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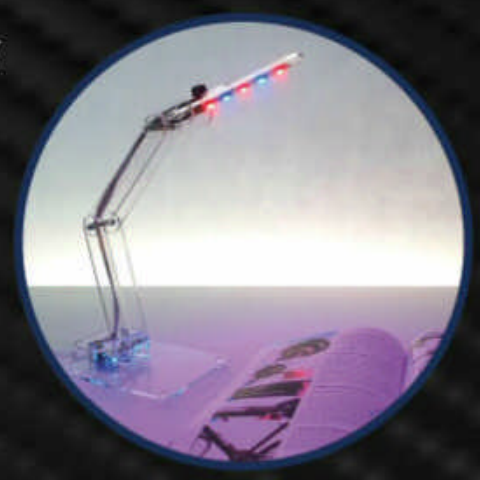

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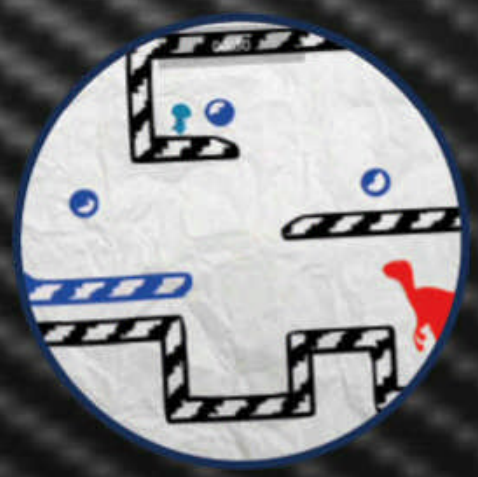

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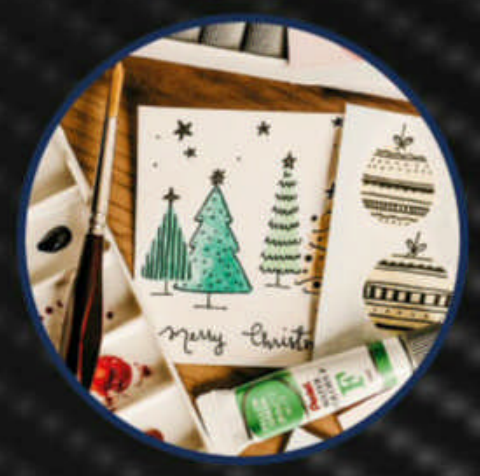

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ISSUE **144**

WELCOME

The magazine that feeds minds!

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"Brain cells fire signals when someone looks at us, stopping when the gaze moves away"

20 Spooky explanations for the world's creepiest curiosities, page 20

For the **How It Works** team and many of our readers in the Northern Hemisphere, the nights have been closing in and the weather has gotten a lot colder in recent weeks. Our feet and hands turn to the warmth of our hearths as our minds turn to ghost stories. Science, technology and nature have their fair share of spooky phenomena too, much of which isn't made any less weird or chilling by explaining them. We've described 20 of the world's creepiest curiosities for you in this Halloween-season issue of **How It Works**. So make yourself a hot drink, wrap yourself in your duvet and prepare to be thrilled.

Enjoy the issue!

Ben Editor

Meet the team...

Nikole
Production Editor
Space is dark, empty and mysterious, but that's not all that makes it creepy. Explore spooky space phenomena on page 64.

Scott
Staff Writer
Discover the botanical vampires hiding in plain sight and learn how they suck the life out of their leafy hosts on page 48.

Baljeet
Research Editor
Witchcraft was a very real fear for the people of Salem, with many accusing their neighbours and friends. Find out why on page 38.

Duncan
Senior Art Editor
These big-wheeled trucks are masters of crushing cars and other stupendous stunts. Learn all about monster trucks on page 54.

Ailsa
Staff Writer
COVID swab test results can take 48 hours, but what happens during this time? Hear from the test lab scientists on page 36.

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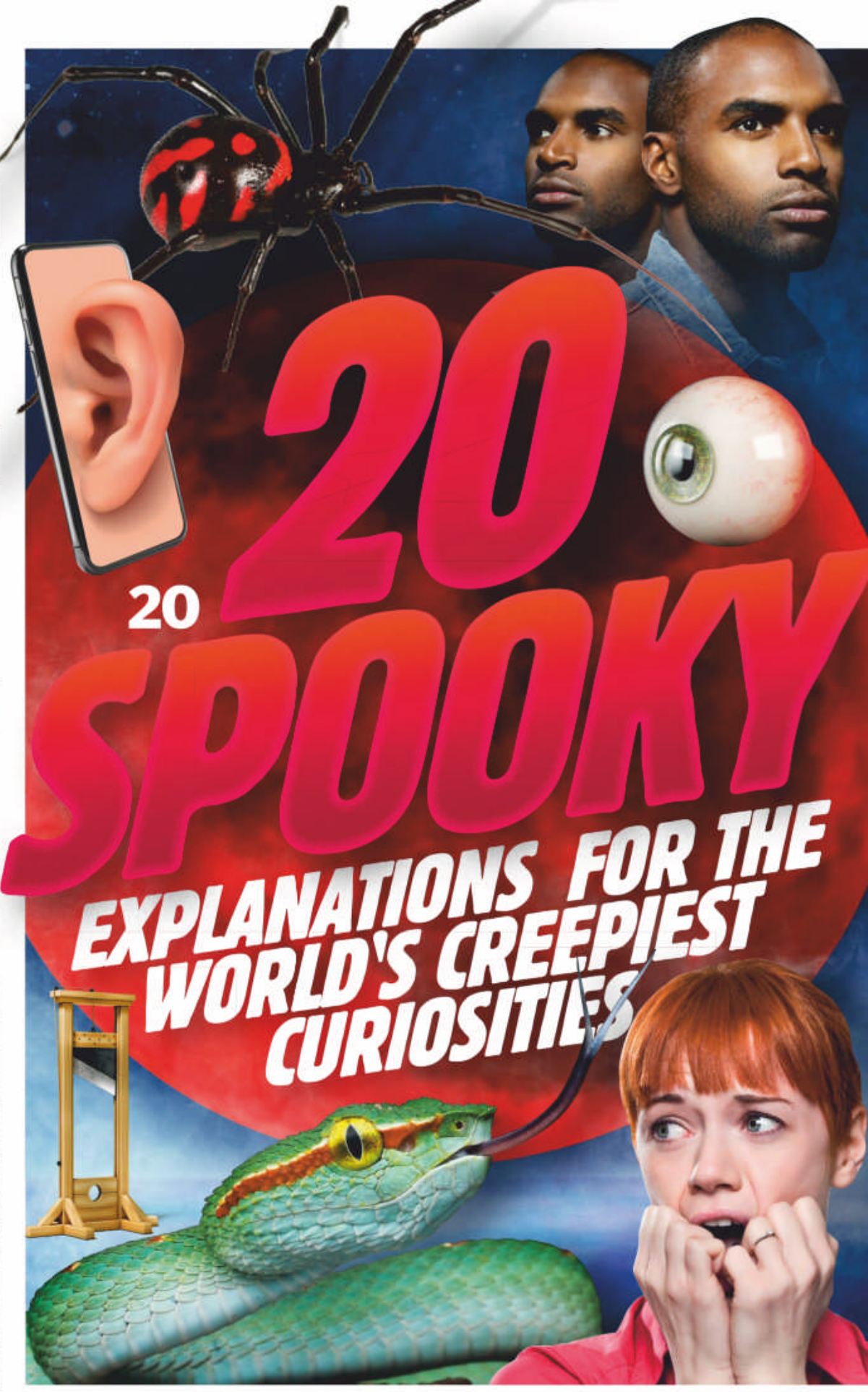

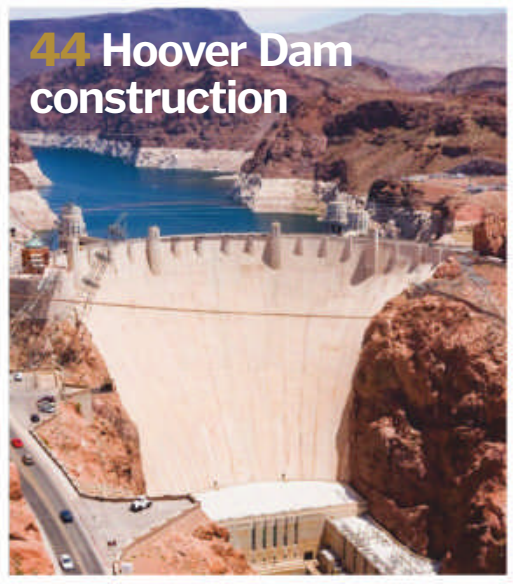

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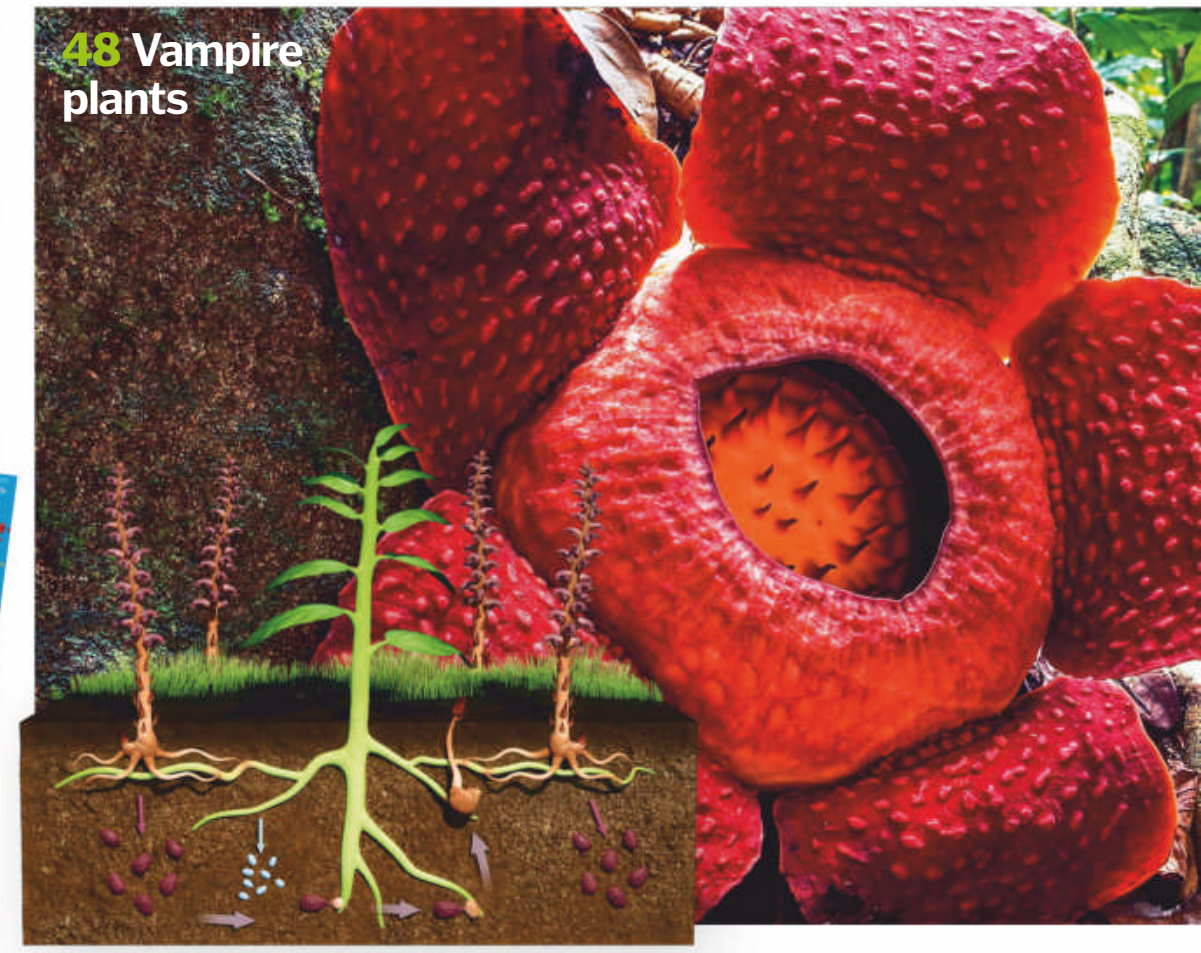

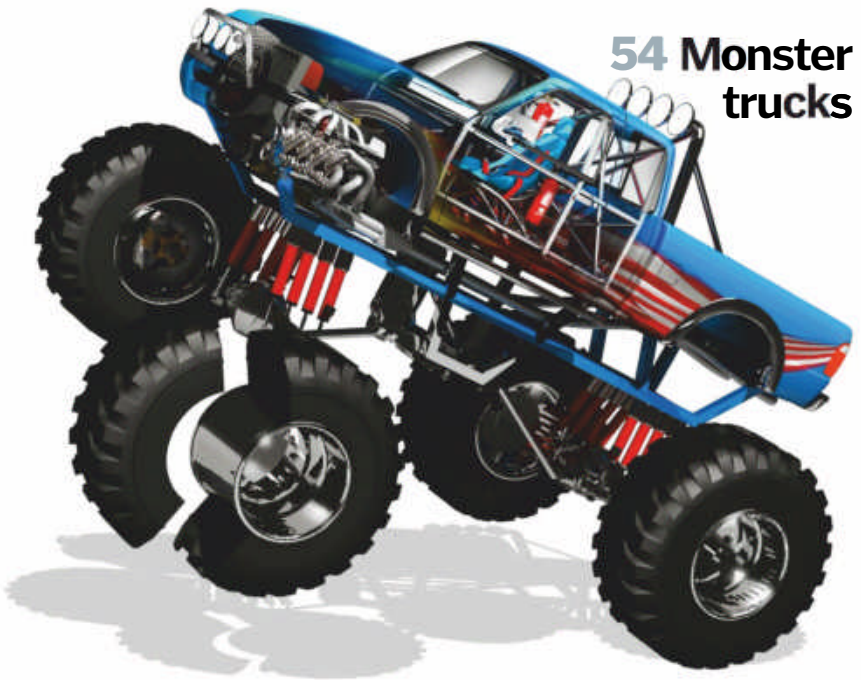

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REGULARS

LIZARD FROM HELL

Looking into the devilish eyes of this cryptic creature, it's easy to understand why biologist George Boulenger named it the satanic leaf-tailed gecko (Uroplatus phantasticus). Weighing just six grams as an adult, these miniature reptiles can be hard to spot among the foliage of Madagascar's forests. Evolution has given this gecko the ability to seamlessly blend in with its leafy surroundings, with skin that looks like leaf litter and a tail that could be mistaken for a leaf. It's not only a great way to camouflage from predators but also serves as a decoy. In the same way as a crab has the ability to throw off one of its claws during a fight, when this gecko feels threatened it will detach its tail.

© Alamy

CHURCH OF SKULLS

Hidden deep in the heart of Milan is a small Italian catholic church unlike most you may have seen. Dating back to the 13th century, San Bernardino alle Ossa was built by a nearby hospital. Beginning as a small ossuary to house the bones from the overflowing hospital graveyard, it was then transformed into a church, with the skulls of ex-patients, monastic medical staff and inmates of local prisons used to decorate the walls. Towering above the skulls and bones of those long gone is a heavenly fresco called the “Triumph of Souls among Flying Angels”. It’s thought that this angelic scene serves as a sign of hope for the afterlife for the dead souls that surround it.

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TECH

Nuclear fusion reactors here by 2025

Words by Charles Q. Choi

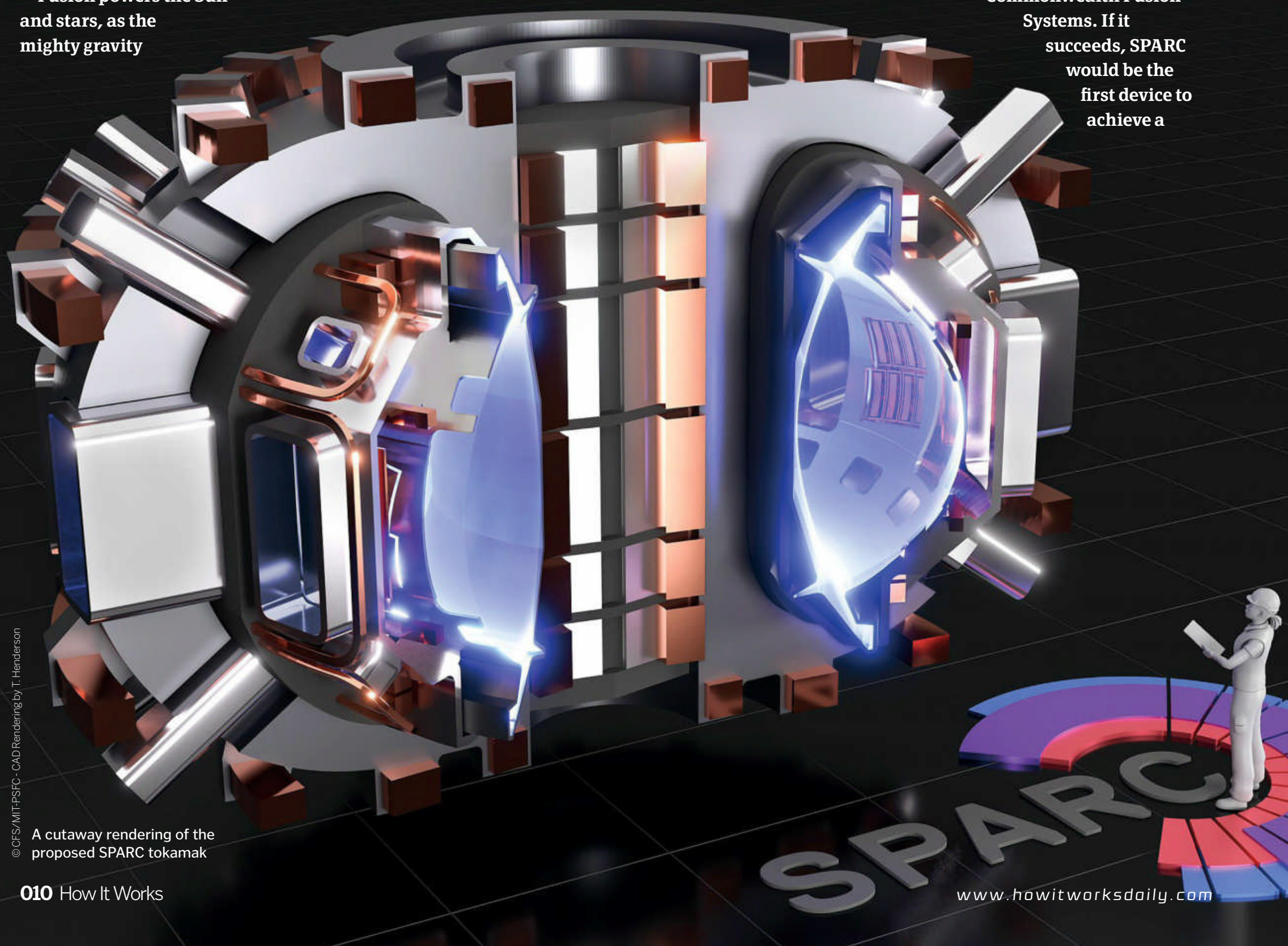
A viable nuclear fusion reactor, one that spits out more energy than it consumes, could be here as soon as 2025. If a fusion reactor reaches that milestone, it could pave the way for a massive generation of clean energy.

During fusion, atomic nuclei are forced together to form heavier atoms. When the mass of the resulting atoms is less than the mass of the atoms that went into their creation, the excess mass is converted to energy, liberating an extraordinary amount of light and heat.

Fusion powers the Sun and stars, as the mighty gravity at their hearts fuses hydrogen to create helium. But an enormous amount of energy is needed to force atoms to fuse together, which occurs at temperatures of at least 100 million degrees Celsius. However, such reactions can generate far more energy than they require.

At the same time, fusion doesn't produce greenhouse gases such as carbon dioxide, which drive global warming, nor does it generate other pollutants. And the fuel for fusion, such as the element hydrogen, is plentiful enough on Earth to meet all of humanity's energy needs for millions of years, making it truly sustainable.

Most experimental fusion reactors employ a doughnut-shaped Russian design called a tokamak. These designs use powerful magnetic fields to confine a cloud of plasma, or ionised gas, at extreme temperatures, high enough for atoms to fuse together. The new device, called the Soonest/Smallest Private-Funded Affordable Robust Compact (SPARC) reactor, is being developed by scientists at the Massachusetts Institute of Technology (MIT) and a spin-off company, Commonwealth Fusion Systems. If it succeeds, SPARC would be the first device to achieve a



© CFS/MIT-PSFC - CAD Rendering by T. Henderson

A cutaway rendering of the proposed SPARC tokamak

'burning plasma', in which the heat from all the fusion reactions keeps fusion going without the need to pump in extra energy. No one has ever been able to harness the power of burning plasma in a controlled reaction here on Earth, and more research is needed before SPARC can do so. The SPARC project, launched in 2018, is scheduled to begin construction next June, with the reactor starting operations in 2025. This is far faster than the world's largest fusion power project, known as the International Thermonuclear Experimental Reactor (ITER).

One advantage that SPARC may have over ITER is that SPARC's magnets are designed to confine its plasma. SPARC will use so-called high-temperature superconducting magnets that only became commercially available in the past three to five years, long after ITER was first designed. These new magnets can produce far more powerful magnetic fields than ITER's: a maximum of 21 teslas, compared with ITER's maximum of 12 teslas. In comparison, Earth's magnetic field ranges in strength from 30 to 60 millionths of a tesla.

These powerful magnets suggest the core of SPARC can be about three-times smaller in diameter, and 60- to 70-times smaller in volume than the heart of ITER, which is slated to be six metres wide. "That dramatic reduction in size is accompanied by a reduction in weight and cost," said Martin Greenwald, a plasma physicist at MIT. SPARC is expected to generate at least twice as much as ten-times more energy as is pumped in. The heat from a fusion reactor would generate steam. This steam would then drive a turbine and electrical generator in the same way most electricity is produced nowadays.

"Fusion power plants could be one-to-one replacements for fossil fuel plants, and you wouldn't have to restructure electrical grids for them," Greenwald said. In contrast, renewable energy sources such as solar and wind "are not accommodated well by the current design of electric grids". It's hoped that SPARC-inspired fusion power plants would generate between 250 and 1,000 megawatts of electricity. "In the current power market of the US, power plants typically generate between 100 and 500 megawatts," Greenwald said.

© NASA

The trio includes the fourth woman ever to receive the physics Nobel prize

SPACE

Physics Nobel Prize awarded for black hole discoveries

Words by **Jeanna Bryner**

The Nobel Prize in Physics has been awarded to three scientists for their work involving some of the cosmos' most mysterious, darkest secrets: black holes. Roger Penrose of the University of Oxford in the UK received half of the prize "for the discovery that black hole formation is a robust prediction of the general theory of relativity," while Andrea Ghez of the University of California, Los Angeles and Reinhard Genzel of the University of Bonn and the Max Planck Institute for Extraterrestrial Physics in Germany jointly shared the other half "for the discovery of a supermassive compact object at the centre of our galaxy".

For his part, Penrose showed with eloquent mathematical models that the very existence of black holes is a direct consequence of Albert Einstein's most famous theory; in fact, Einstein didn't believe such heavyweights – objects that devour everything that comes within their reach – even existed.

Even so, his theory of general relativity predicts that gravity results from the warping of space-time. Under this theory, massive objects like black holes put cosmic dents in this space-time fabric so that other nearby objects can't help but fall into these gravity divots. One of the predictions to come out of general relativity is that black holes have an event horizon, a demarcation beyond which nothing, not even light, can escape. Penrose found that at the heart of black holes lies an infinitely dense core called a singularity, where the laws of nature break down.

For their part, teams led by Ghez and Genzel revealed the dark secret at the centre of the Milky Way. Since the early 1990s, by focusing on a region at the heart of our galaxy called Sagittarius A*, Ghez and Genzel independently found that some super-heavy object there is pulling on clusters of stars and causing them to whiz around at mind-bending speeds. Their teams discovered that an object weighing in at a whopping 4 million solar masses is packed into a spot no larger than our Solar System.

"The discoveries of this year's laureates have broken new ground in the study of compact and supermassive objects," said David Haviland, chair of the Nobel Committee for Physics. "But these exotic objects still pose many questions that beg for answers and motivate future research. Not only questions about their inner structure, but also questions about how to test our theory of gravity under the extreme conditions in the immediate vicinity of a black hole." Penrose will receive half of the 10 million kronor (approximately £866,000) Nobel Prize, while Ghez and Genzel will split the other half.

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SPACE

Something ripped the skin off this star before it died

Words by Rafi Letzter

A giant star died, blasting its guts into space. But before the star detonated, some stellar thief had already stolen the giant's skin. Now astrophysicists think they've identified the culprit: a nearby star blasting its own guts out.

Supernovae are fairly common in space. Most very large stars end their lives as stellar explosions. When they die, hot clouds of gas spread across space. Those clouds are full of the heavy atoms the stars fused into being in the nuclear engines of their bellies.

Usually there's hydrogen in the clouds too. These simple, single-proton atoms remain in the outer skin of the star, where pressure and heat never got high enough to fuse them together into heavier elements. It's unspent fuel, in other words. Sometimes, however, that skin vanishes. Usually gravity from a nearby star, such as a binary twin in the same system, strips that outer envelope of hydrogen away. Sometimes, however, it's not clear where all the hydrogen-rich skin went. For a long time that was the case for the supernova remnant Cassiopeia A (Cas A), but not anymore.

Researchers describe a scenario that could produce a solitary, 'stripped-envelope' supernova like Cas A's. Their story, like most skinless supernova tales, begins with two sibling stars in a tight binary orbit around one another. Critically, these siblings were born at the same time in the same place and at nearly the same mass. As a result the two stars would also live for similar lengths of time, become swollen red giants in their old age and die in short succession, one after the other. If Cas A's sibling went first, that first supernova explosion would have effectively sandblasted the surviving big red supergiant – in other words, Cas A – just as Cas A was nearing the end of its own life.

A team at the ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav) in Melbourne, Australia, simulated how this would work. Their simulations showed that between 50 and 90 per cent of the surviving star's outer skin of hydrogen gets blasted away in the wind of the first supernova as long as the two stars orbit very close together. "This is enough for the second supernova of the binary system to become a stripped-envelope supernova, confirming that our proposed scenario is plausible," says Ryosuke Hirai, an OzGrav astrophysicist.

It's also possible for the first supernova to rip off just some of its sibling's envelope, causing that star to be in an unstable state; in this scenario, the instability leads to more hydrogen being expelled from the star before it goes supernova. The star would react like it had just been shot with a shotgun, convulsing and losing fuel to space before its demise.

If this version of star death happens, it's likely rare, occurring in just 0.35 to one per cent of supernovae. The scenario hasn't yet been confirmed, though it might apply to two other known supernovae: RX J1713.7-3946 and G11.2-0.3. But Cas A is the most exciting example for a simple reason.

The simulation predicts that there should still be a signature of that envelope lost in the first supernova: a puff of hydrogen-rich gas drifting through space 30 to 300 light years away from the supernova remnant. In the case of Cas A they found one such puff, just 50 light years away, precisely fitting what their model predicted.

Cassiopeia A, the remnant of a 'stripped-envelope supernova', may have actually taken its form from two supernovae in quick succession

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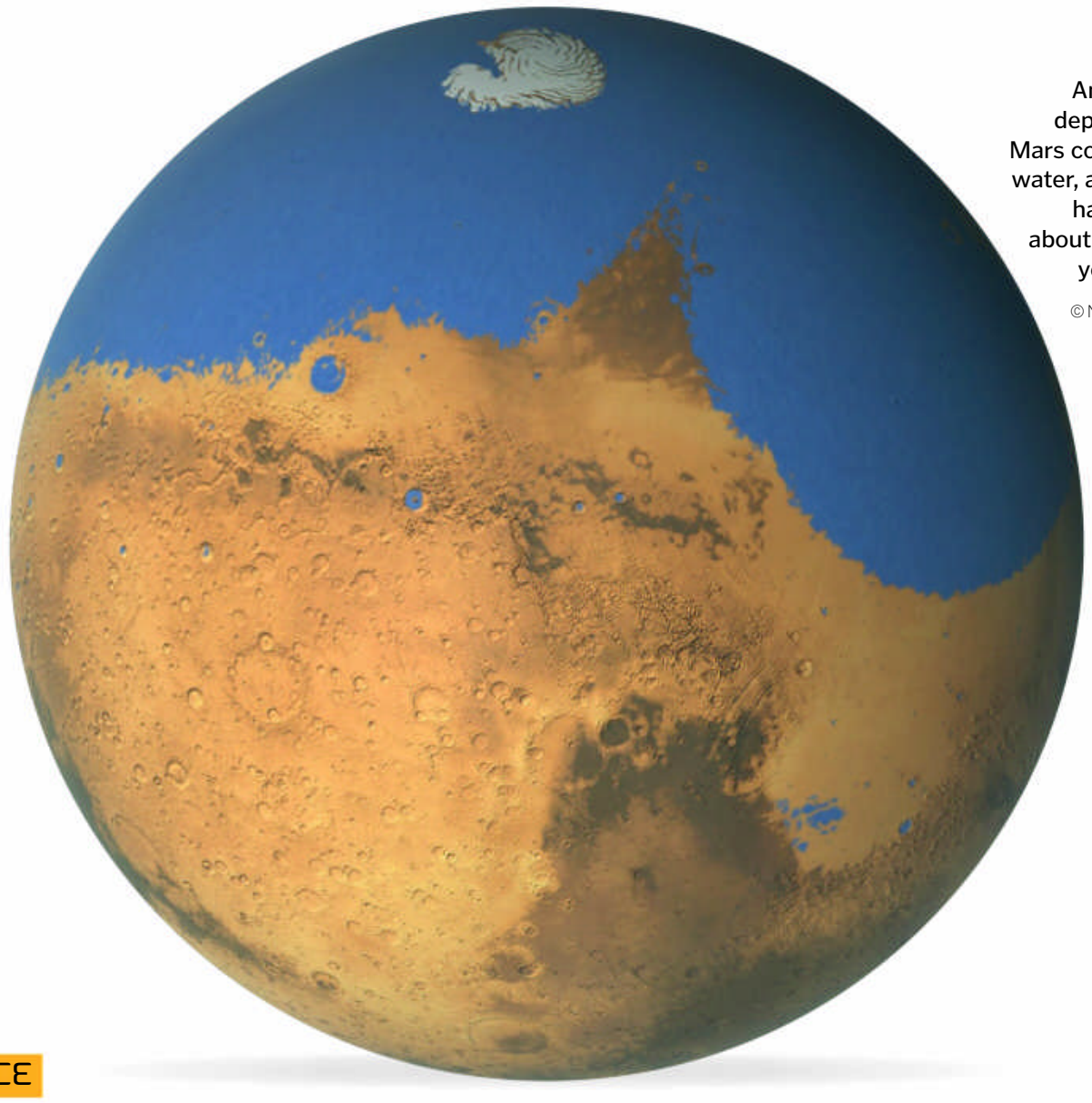

An artist's depiction of Mars covered in water, as it may have been about 4 billion years ago

© NASA/GSFC

SPACE

Four lakes may be under Mars' south pole

Words by Charles Q. Choi

Remnants of water once found on the surface of Mars may be hidden in a handful of small lakes below the Red Planet's south pole, and more could exist. For decades researchers have suspected that water lurks below the polar ice caps of Mars, just as it does here on Earth. In 2018 scientists detected evidence for such a reservoir on the Red Planet, signs of a lake about 19 kilometres across and hidden below about 1.5 kilometres of ice at the south pole of Mars.

At the time the researchers said studying this underground pool of water could yield insights on the past and present chances for life on Mars. However, scientists had many more questions than answers about the origin, composition and longevity of this lake and its water. To learn more about this hidden water, researchers have used the Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) instrument on board the European Space Agency's Mars Express to scan a 250-by-300-kilometre area surrounding the suspected underground lake.

It's confirmed the liquid nature of the previously observed lake, narrowing down its dimensions to about 20-by-30 kilometres in size. However, it can't be said how deep this lake extends, as the radio waves from MARSIS cannot penetrate salty water. Moreover, Elena Pettinelli, a geophysicist at Roma Tre University in Rome, and her colleagues identified three other lakes approximately ten-by-ten kilometres in size. Strips of dry rock separate these smaller patches of water from the main lake. The researchers suggested these lakes are extraordinarily salty. High brine content would keep their water liquid despite the extremely cold conditions at the base of the glaciers at Mars' south pole.

Although Martian polar ice may be melting a little due to warm noontime temperatures, it's not likely that such ongoing processes formed these lakes. Instead it's believed this saltwater may be the remnants of a larger body of water now lost from the surface, and may be millions or even billions of years old. Scientists have considered the possibility that geothermal activity might have melted polar ice to form the underground lakes, but that explanation was plausible when there was only one such body of water. Forming several lakes this way might require a huge geothermal anomaly. "I don't think it is physically possible, given what we know," said Pettinelli.

Instead these lakes may have formed due to a warmer global climate in the Martian past. "This is a complex system of water, not just a single pond," said Pettinelli. "It suggests that the conditions that created these lakes might have been more spread across the region, that there might be other systems like this around."

GLOBAL EYE

HISTORY

59 priest mummies and a god unearthed in Egypt

Words by Owen Jarus

In the span of a month, the number of sealed coffins found at a dig in Saqqara in Egypt has ballooned from 13 to 59. The colourful coffins, which date back to Egypt's 26th Dynasty, were found stacked together within or near three burial wells. The mummies are still preserved within the coffins, and hieroglyphic writing on the coffins indicates that many of the mummies were priests.

Beside the coffins they found the remains of 28 small statues. One of the most interesting is a nearly 35-centimetre bronze statue of the god Nefertem, shown wearing a headdress shaped like a lotus blossom. The headdress is made of red agate stone, turquoise and lapis lazuli. In ancient Egyptian mythology, Nefertem was associated with lotus flowers and was the son of Ptah, a creator god who was popular in Memphis, the first capital.

Another small statue depicts the god Ptah-Soker, an amalgamation of the gods Ptah and Soker. "Saqqara was called Saqqara because of the god Soker. In the Late Period – [the time the coffins date to] – there was a combination of the god Ptah of Memphis with Soker," said Zahi Hawass, a former Egyptian minister of antiquities. "This is unique. I have never seen this before," says Hawass, regarding the Ptah-Soker statue.

Work is still ongoing, and more coffins and other artefacts are expected to be discovered soon.

© Getty

Coffins dating back more than 2,500 years have been unearthed from the 26th Dynasty of Egypt

IN ASSOCIATION WITH LIVESCIENCE

ANIMALS

Fossils of Ice Age manatees discovered

Words by Stephanie Pappas

Today's manatees often summer off the coast of Texas and Florida, heading farther south towards warmer waters in winter. New fossils suggest that their Ice Age ancestors may have made the same migrations.

Eight Pleistocene manatee bones – ribs, jaws and other fragments – found along the Texas coast reveal that manatees either lived in the area or visited it regularly between 11,000 and 240,000 years ago. This finding is surprising because it indicates that either Texas coastal waters were warmer than expected during the Ice Age, or ancient manatees were more tolerant of cold than their modern relatives.

Six of the fossils come from private collections donated to Sam Houston State University (SHSU) in Huntsville over 50 years. The other two are in the collection of the Jackson School Museum of Earth History at the University of Texas, Austin. "We have them from one decade to another, so we know it's not from some old manatee that washed up, and we have them from different places," said SHSU Natural History Collections curator William Godwin. "All these lines of evidence support that manatee bones were coming up in a constant way."

All but one of the bones come from *Trichechus manatus*, the same species that traverses Gulf Coast waters today, placidly grazing on sea grasses. An upper jawbone, donated by US representative Brian Babin, belongs to an extinct subspecies, *Trichechus manatus bakerorum*.

© Getty

Manatees lived in Texas during the last ice age, according to fossil evidence found along beaches

© Getty

Sleep deprivation may affect time's passing

HEALTH

'Tired' brain cells may distort your sense of time

Words by **Yasemin Saplakoglu**

Time in the brain doesn't follow the steady ticking of the world's most precise clocks. Instead it seems to fly by at one moment and practically stand still at others. This distorted sense of time may be caused, in part, by brain cells getting tired. When the brain has been exposed to the same exact time interval too many times, neurons or brain cells get overstimulated and fire less often. However, our perception of time is complicated, and many other factors may also explain why time moves slowly sometimes and quickly at others.

We have only very recently begun to understand how our brains perceive time. It was only in 2015 that researchers found the first evidence of neurons whose activity fluctuates with our perception of time. But it wasn't clear if these neurons, found in a small brain region called the supramarginal gyrus (SMG), were keeping accurate time for the brain or creating a subjective experience of time.

In a recent study researchers used a 'time illusion' on 18 healthy volunteers to figure it out. They hooked participants up to a functional magnetic resonance imaging (fMRI) machine that measures brain activity by detecting changes in blood flow. The volunteers then went through an 'adaptation' period, in which they were shown a grey circle on a black background for either 250 milliseconds or 750 milliseconds, 30 times in a row. After this the participants were shown another circle for a set period of time as a 'test stimulus'. They were then told to listen to white noise for a certain amount of time and asked if the test stimulus was longer or shorter than the white noise. They used white noise as a reference because an auditory stimulus isn't affected by the visual adaptation, but the visual test stimulus is.

The researchers found that if the test stimulus was similar in length to the adaptation stimulus in duration, activity in the supramarginal gyrus decreased. In other words, neurons in that region fired less than when they were first exposed to the grey circle. The idea is that this repetition "tired out neurons" that are sensitive to that time duration, said Masamichi Hayashi, a cognitive neuroscientist at the National Institute of Information and Communications Technology in Japan. But "other neurons that are sensitive to other durations [were] still active".

This difference in activity level distorted the participants' perception of time. If exposed to a stimulus longer than the duration the brain was adapted to, the participant overestimated time, and if exposed to a shorter stimulus, the participant underestimated time.

This can distort our sense of time in the real world. An audience at a piano concert may adapt to a musical tempo. "Your audience may feel your musical tempo subjectively slower than it actually is after being exposed to music with a faster tempo, even if you are playing the music at the correct tempo," Hayashi said. But "we cannot say at this point that neuron fatigue 'caused' skewed time perception because our study only showed a correlation between neuron fatigue and distortion of subjective time".

PLANET EARTH

Early life on Earth may have breathed arsenic

Words by **Carly Cassella**

Billions of years ago, long before oxygen was readily available, the notorious poison arsenic could have been the compound that breathed new life into our planet. In Chile's Atacama Desert, in a place called Laguna La Brava, scientists have been studying a purple ribbon of photosynthetic microbes living in a hypersaline lake that's permanently free of oxygen.

"I have been working with microbial mats for about 35 years or so," says geoscientist Pieter Visscher from the University of Connecticut. "This is the only system on Earth where I could find a microbial mat that worked absolutely in the absence of oxygen."

Microbial mats, which fossilise into stromatolites, have been abundant on Earth for at least 3.5 billion years, and yet for the first billion years of their existence there was no oxygen for photosynthesis. How these life forms survived in such extreme conditions is still unknown, but examining stromatolites and extremophiles living today, researchers have figured out a handful of possibilities.

While iron, sulphur and hydrogen have long been proposed as possible replacements for oxygen, it wasn't until the discovery of 'arsenotrophy' in California's hypersaline Searles Lake and Mono Lake that arsenic also became a contender. Since then stromatolites from the Tumbiana Formation in Western Australia have revealed that trapping light and arsenic was once a valid mode of photosynthesis in the Precambrian Era. The same couldn't be said of iron or sulphur.

The La Brava life forms closely resemble a purple sulphur bacterium called *Ectothiorhodospira sp*. which was recently found in an arsenic-rich lake in Nevada and which appears to photosynthesise by oxidising the compound arsenite into a different form, arsenate. While more research needs to verify whether the La Brava microbes also metabolise arsenite, initial research found the rushing water surrounding these mats is heavily laden with hydrogen sulphide and arsenic.

If the authors are right and the La Brava microbes are indeed 'breathing' arsenic, these life forms would be the first to do so in a permanently and completely oxygen-free microbial mat, similar to what we would expect in Precambrian environments. As such, its mats are a great model for understanding some of the possible earliest life forms on our planet.

While genomic research suggests the La Brava mats have the tools to metabolise arsenic and sulphur, its arsenate reduction appears to be more effective than its sulphate reduction. There's strong evidence that both pathways exist, and these would have been enough to support extensive microbial mats in the early days of life on Earth.

Despite being super-salty and oxygen-free, La Brava lagoon in the Atacama Desert is host to a peculiar type of microbes

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Taenia solium usually requires pigs to have contact with human faeces to complete their life cycle

HEALTH

Woman's headache was actually a brain tapeworm

Words by Rachael Rettner

A young woman in Australia was found to have tapeworm larvae lurking in her brain, a very unusual diagnosis considering she had no risk factors for the condition. It's believed to be the first 'locally acquired' case of the disease in Australia, that is, in someone who hadn't travelled out of the country.

The 25-year-old woman went to the hospital after experiencing headaches for a week. An MRI of her head revealed a single brain lesion, which doctors suspected was either a brain abscess or tumour. But when doctors performed brain surgery to remove the lesion, they got a surprise. The lesion was really a cyst, and it wasn't made of human tissue. Further tests revealed that the cyst contained tapeworm larvae.

The woman was diagnosed with neurocysticercosis, a parasitic disease that occurs when a person ingests microscopic eggs from a pork tapeworm (*Taenia solium*). When the eggs hatch, the larvae can travel throughout the body, including to the brain, muscles, skin and eyes, where they form cysts. After the cyst was removed, the woman did not need further treatment for the infection.

In Australia, all previous reported cases have been among people who either immigrated to the county or travelled to areas where the disease is endemic before returning to Australia. Exactly how the Australian woman caught the disease remains a mystery.

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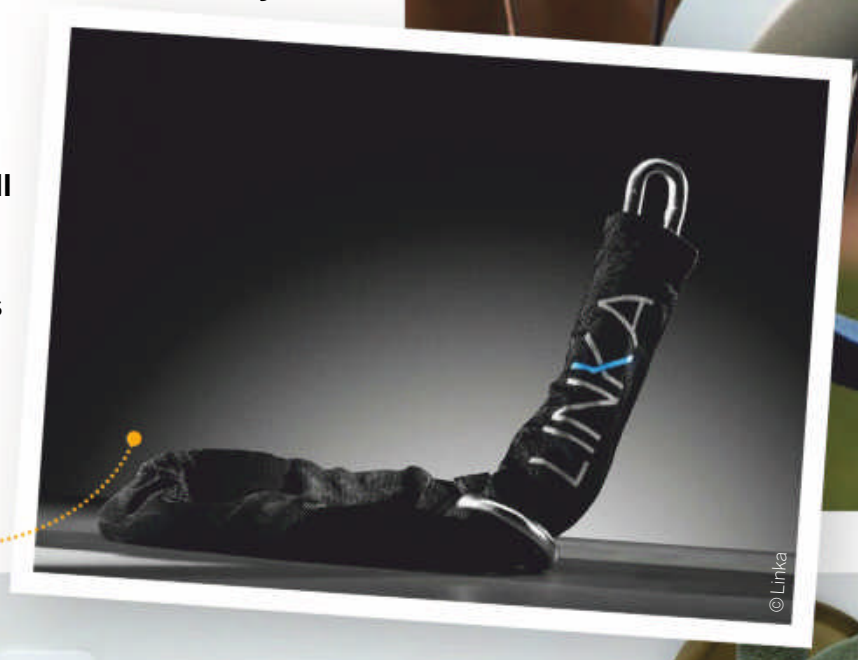
eu.linkalock.com / www.linkalock.com

Upgrade your bicycle security with this auto-unlocking bike lock. Sleek and robust, this high-tech lock makes bike security simple with keyless access. Controlled via your smartphone, this smart lock will clamp down at the touch of a button and will automatically unlock when your phone is within close proximity. The Linka app will also alert your phone when it detects any unexpected movement, indicating someone is tampering with the device, and will deliver a deafening siren to ward off any thieves.



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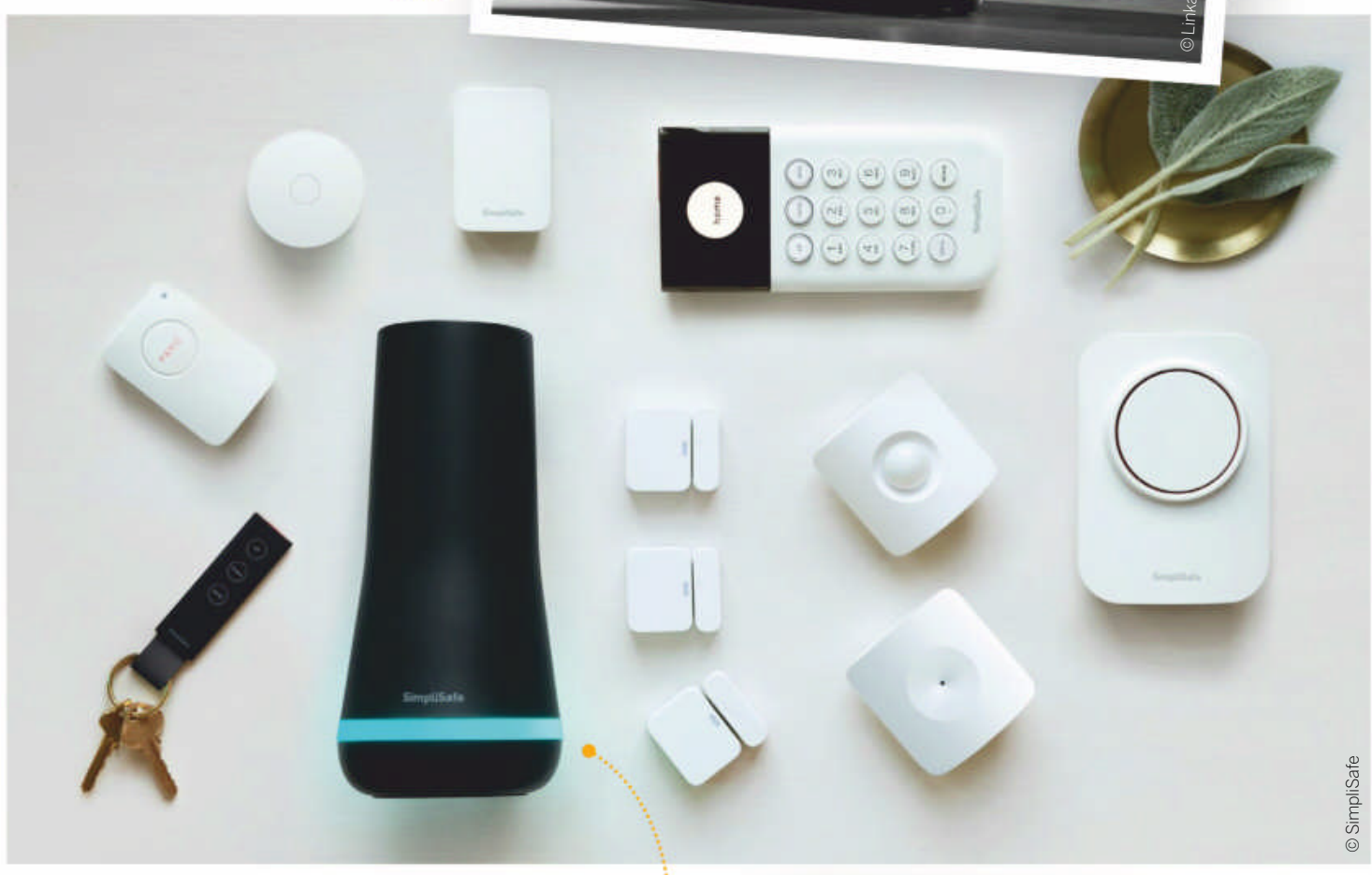


© SimpliSafe

SimpliSafe: The Bamburgh

Price: **£504 (approx. $656.24)**
www.simplisafe.co.uk

If you're looking for a customisable or full-house security system, SimpliSafe could be for you. The Bamburgh package comes jam-packed with security technology: from glass-breaker sensors and surveillance cameras to entry sensors and even a panic button, this whole-house system allows you to secure every inch of your home. The included motion sensors are also designed to detect human body heat so as to not confuse your household pets as possible intruders.

© ring

Video Doorbell 3

Price: **£179 / $199.99**
en-uk.ring.com / shop.ring.com

The Video Doorbell 3 by Ring allows you to keep tabs on your front door at all times wherever you are in the world. Once installed, the smart doorbell will alert your phone when someone's at your door. With its equipped camera and microphone you can communicate with your visitor, even if you're not at home. The Video Doorbell 3 is also equipped with some security features, such as video recording and photo capturing for you to save and share, and has a live feature so you can check your porch at the touch of a button.

© Nuki

Nuki

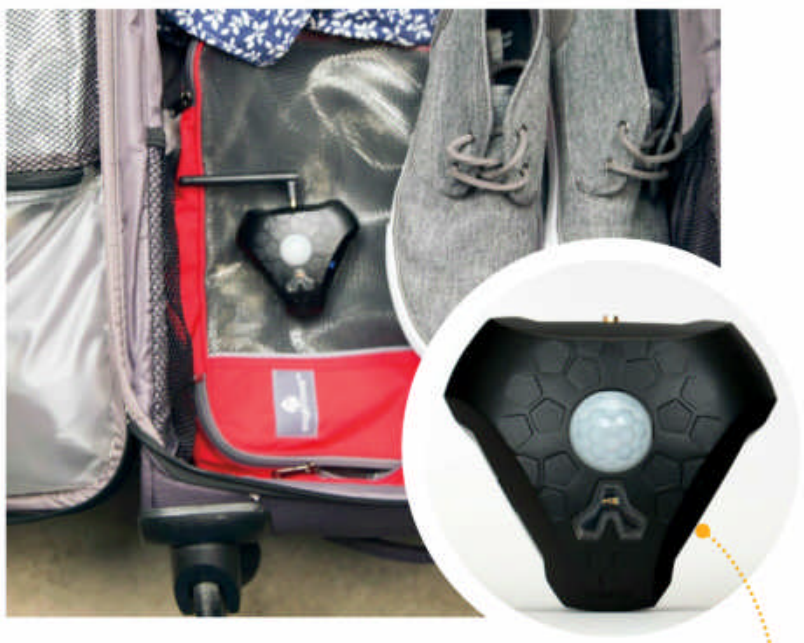
Price: **from £259 (approx. $337.30)**
shop.nuki.io/en-gb/

Turn your smartphone into a smart key with this innovative security system. Using the companion app, you can simply lock and unlock your home at the touch of a button, without the use of traditional keys. Nuki also allows you to designate access permissions to different friends and family for complete control of your home. The app will also alert you to the status of your doors, whether closed or open, remotely. Nuki can also be integrated with other smart home devices, like Google assistant and Amazon Alexa, for voice activation.

Chipolo ONE Ocean Edition

Price: **£27 (approx. $35)**
www.chipolo.net

Wherever you are in the world, the Chipolo ONE Ocean Edition lets you keep tabs on your belongings. The easy-to-follow companion app will show its last known location and even alert you when your possession is a certain distance away in case you've left your keys or wallet at home. Lightweight and water-resistant, this Bluetooth tracker is a great way to keep possessions safe. What makes the Ocean Edition different from other Chipolo ONE devices is that its plastic casing is made from recycled fishing nets, trawls and rope found in the ocean. Chipolo will pledge $1 (about 70 pence) to the non-profit organisation Oceanic Global for each sale.

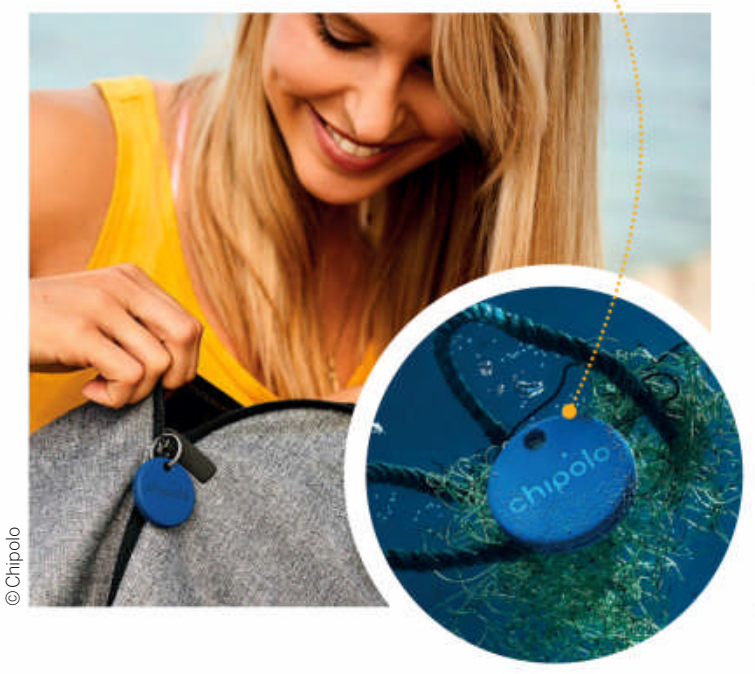


© Simtek

Simtek Wireless Security Sensor

Price: **$250 (approx. £192)**
www.simtek.io

This smart sensor by Simtek keeps you updated if someone has come into contact with your valuables. Whether it's used in your travel case or your home office, using its light and infrared sensors, this device will detect when someone has accessed your belongings and alert your smartphone. There's no need to charge this device, thanks to the one-year battery life it promises. Alerts to your phone are sent over a secure and encrypted connection using a GSM modem, which works in a similar way to the sim card in your phone, meaning there's no need for WiFi or Bluetooth connection.



© Chipolo

APPS & TOOLS

Glasswire

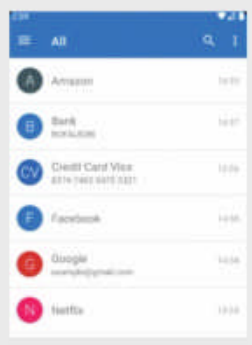
Developer: **SecureMix LLC**
Price: **Free / Google Play**

Keep track of which apps are using your smartphone data and monitor any suspicious app activity with easy-to-read graphics.

My Passwords

Developer: **Erkan Molla**
Price: **Free / Google Play / App Store**

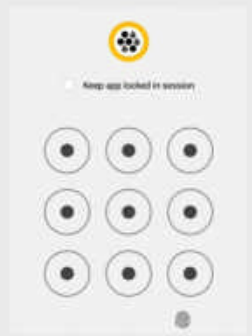
If you struggle to remember all your passwords then you might find this helpful. It securely stores many passwords in a simple list format.



Norton App Lock

Developer: **Norton Labs**
Price: **Free / Google Play**

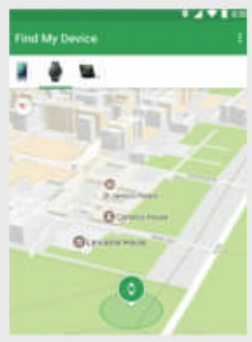
This app keeps other apps safe from prying eyes with unique passwords, PIN numbers or lock screen patterns to restrict access to individual apps.



Google Find My Device

Developer: **Google LLC**
Price: **Free / Google Play**

Using Google Maps, locate your device or its last known location, with the option to remotely erase or lock the device to protect your information.



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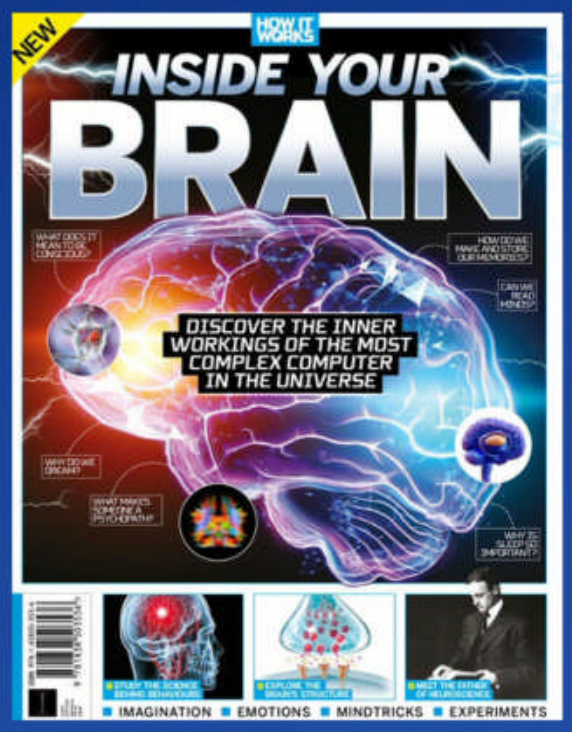

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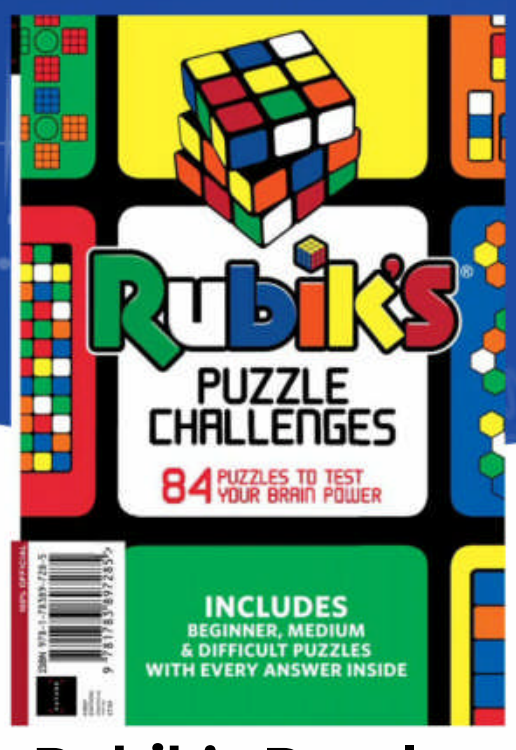

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What makes a black widow so venomous?

OVER 200 SPOOKY

EXPLANATIONS FOR THE WORLD'S CREEPIEST CURIOSITIES

Is another person wearing your face?

Why we 'feel' someone looking at us

Why no one can hear you scream in space

Why Joseph Guillotin hated his deadly idea

Why does the Moon turn red?

Is your phone eavesdropping on you?

Why we get goosebumps when we're scared

How a snake sees with its tongue

WHY DO WE GET GOOSEBUMPS WHEN WE'RE SCARED?

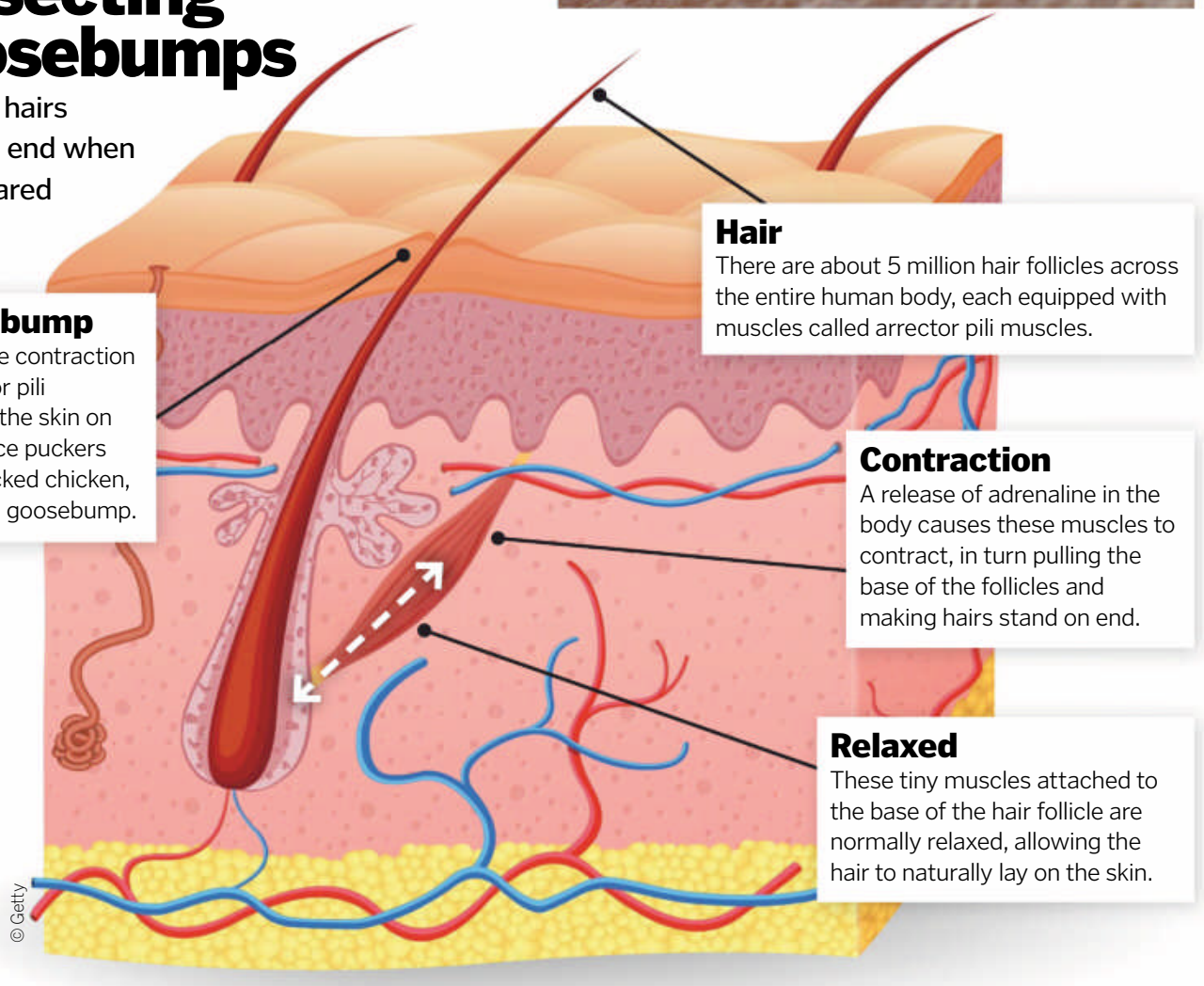
Sitting at home, alone and in the dark, a sudden sense of fear and a swift chill may wash over your body. Sure enough, your hairs stand to attention and goosebumps cover your skin. It's a sensation we've all felt at one time or another, but why does our body react in this way when we're scared? It harkens back to a time when ancient humans faced the daily fear of life-threatening predators. As a result our bodies evolved what we now call a fight-or-flight response. This is a stress response which triggers a release of adrenaline, causing our heart race to rush, our palms to sweat and goosebumps to appear. During this state of fight or flight, the tiny muscles adjacent to each hair contract, making hairs stand on end. Today humans are relatively hairless compared to our animal ancestors. Charles Darwin postulated that at one point in time our ancestors would have been a great deal hairier, and goosebumps would have puffed out their hair to make them look bigger and appear more intimidating to potential predators.


Goosebumps can also help to prevent the loss of heat when we feel cold

© Getty

Dissecting goosebumps

How our hairs stand on end when we're scared



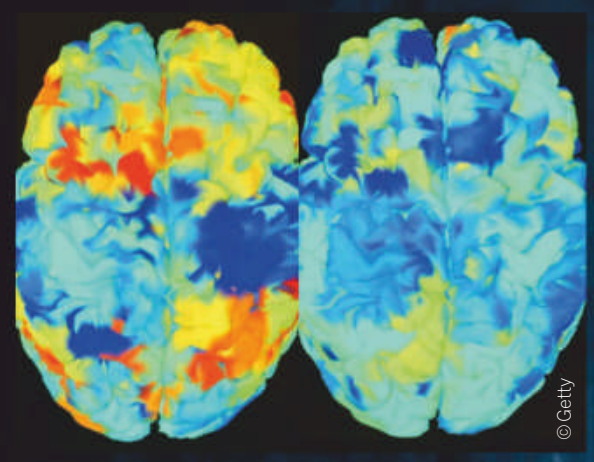
Goosebump
During the contraction of arrector pili muscles, the skin on the surface puckers like a plucked chicken, forming a goosebump.

Hair
There are about 5 million hair follicles across the entire human body, each equipped with muscles called arrector pili muscles.

Contraction
A release of adrenaline in the body causes these muscles to contract, in turn pulling the base of the follicles and making hairs stand on end.

Relaxed
These tiny muscles attached to the base of the hair follicle are normally relaxed, allowing the hair to naturally lay on the skin.

© Getty


Brain patterns were observed using a functional magnetic resonance imaging (fMRI) machine

© Getty

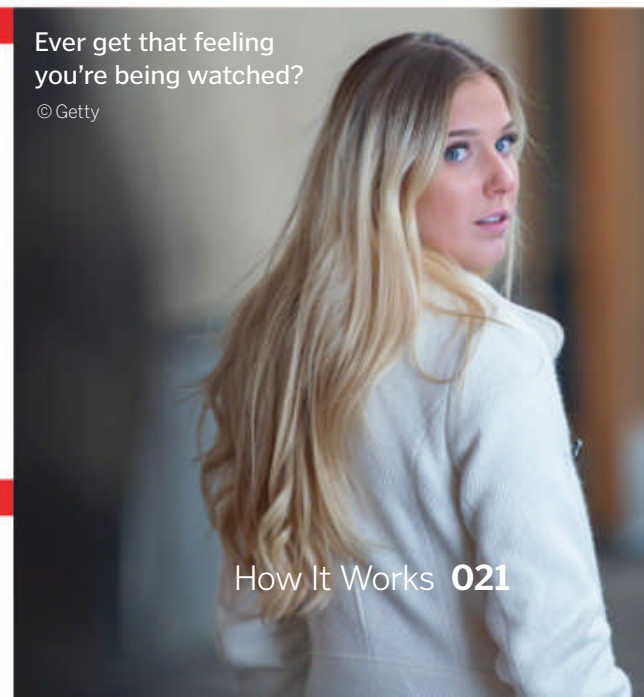
IS MIND-READING POSSIBLE?

Our thoughts are our most private and personal belongings, and the idea that someone could go snooping around inside our heads is terrifying. However, the technology to do so is being developed. Besides the moral and ethical hurdles of mind-reading, the brain is an extremely complex organ. Taking it one step at a time, researchers have been analysing the electrical patterns we produce in the brain when we think of something, such as an object, number or even a sentence. The researchers can then identify and decipher distinct patterns associated with those thoughts in the hope of building a neural dictionary of patterns.

The technology is still in its relative infancy, with years of development needed before complex thoughts can be interpreted. Currently this is being developed to offer insights into the way our brains work, rather than for alternative medical treatments. However, the potential of mind-reading technology is wide-reaching. From understanding autism to predicting a person's decision-making, once you can peer inside the mind, the possibilities are endless.

HOW DO YOU KNOW WHEN SOMEONE IS WATCHING YOU?

Do you ever get a nagging feeling that someone is staring at you? Is it really possible for us to have a six sense of when we're being watched? Studies have found that a single brain cell fires signals when someone looks at us, stopping when their gaze moves away. This was put to the test in 2013 on a patient with cortical blindness. The patient's visual cortex in the brain was damaged, but the brain still received information from the eyes. What was interesting was that the region of the brain that responds to potential threats, called the amygdala, became active when someone stared at the patient. This innate six sense most likely evolved in ancestral humans as a way to detect when a predator was nearby, giving them the chance to escape.


Ever get that feeling you're being watched?

© Getty

WHAT IS LURKING AT THE BOTTOM OF THE OCEAN?

Fewer people have seen the deepest parts of our oceans than have walked on the Moon, so our knowledge of what swims in the deep blue is relatively small. The deepest region of the ocean is called the hadal zone, which begins around six kilometres below the surface. This largely unexplored region consists of trenches formed by Earth's tectonic plates and is inhabited by marine life that can withstand its extreme pressures and lack of sunlight. Some crustaceans and even species of fish, such as the hadal snailfish, have been observed in the zone as deep as eight kilometres below the surface.

A squat lobster found in th e Mariana Trench, the deepest part the ocean

© Alamy

WHAT CAUSES A BLOOD MOON?

Every year or so our lunar neighbour rises in the sky with an eerie crimson glow, known as a blood Moon. It's a phenomenon that typically happens around May, and occurs during a lunar eclipse. This is similar to a solar eclipse, whereby the Moon and Sun perfectly align, blocking our view of the Sun. During a lunar eclipse, however, it is Earth that is blocking most sunlight from the Moon. Any light that does make it to the surface of the Moon passes through Earth's atmosphere. As the visible spectrum of light travels through our atmosphere, blue wavelengths are scattered, leaving red wavelengths to journey to the Moon and giving it a reddish hue. Throughout the year there are other occasions when the Moon appears ruddy, and they're often mistaken for a true blood Moon – this is due to pollution, cloud cover or debris in the atmosphere.

The next blood Moon will occur on 26 May 2021

© Getty

WHY DO WE HAVE NIGHTMARES?

Typically people dream for around two hours a night. During this portion of rest, called rapid eye movement (REM) sleep, is when nightmares can creep in. Sometimes referred to as 'threat rehearsal', it's believed that nightmares occur to prepare us for the possible dangers we might face in real life, although many nightmares are stress-related. At some point during human evolution nightmares may have served a purpose in bringing real-world dangers to our attention and keeping us alert to potential threats. However, in a world where we're no longer chased by prehistoric predators or battling the elements, do nightmares still have a role to play?

© Getty

Losing your teeth is one of the most common nightmares

Although the dangers that may have birthed this neurological function are long forgotten, modern threats such as house fires, car crashes and murder keep nightmares alive. There is, however, a way to battle against them before you head to bed. Some suggest rehearsing an alternative ending to any recurring nightmares while awake, and trying to understand any reasons behind your nightmares is paramount.

Inside the nightmare

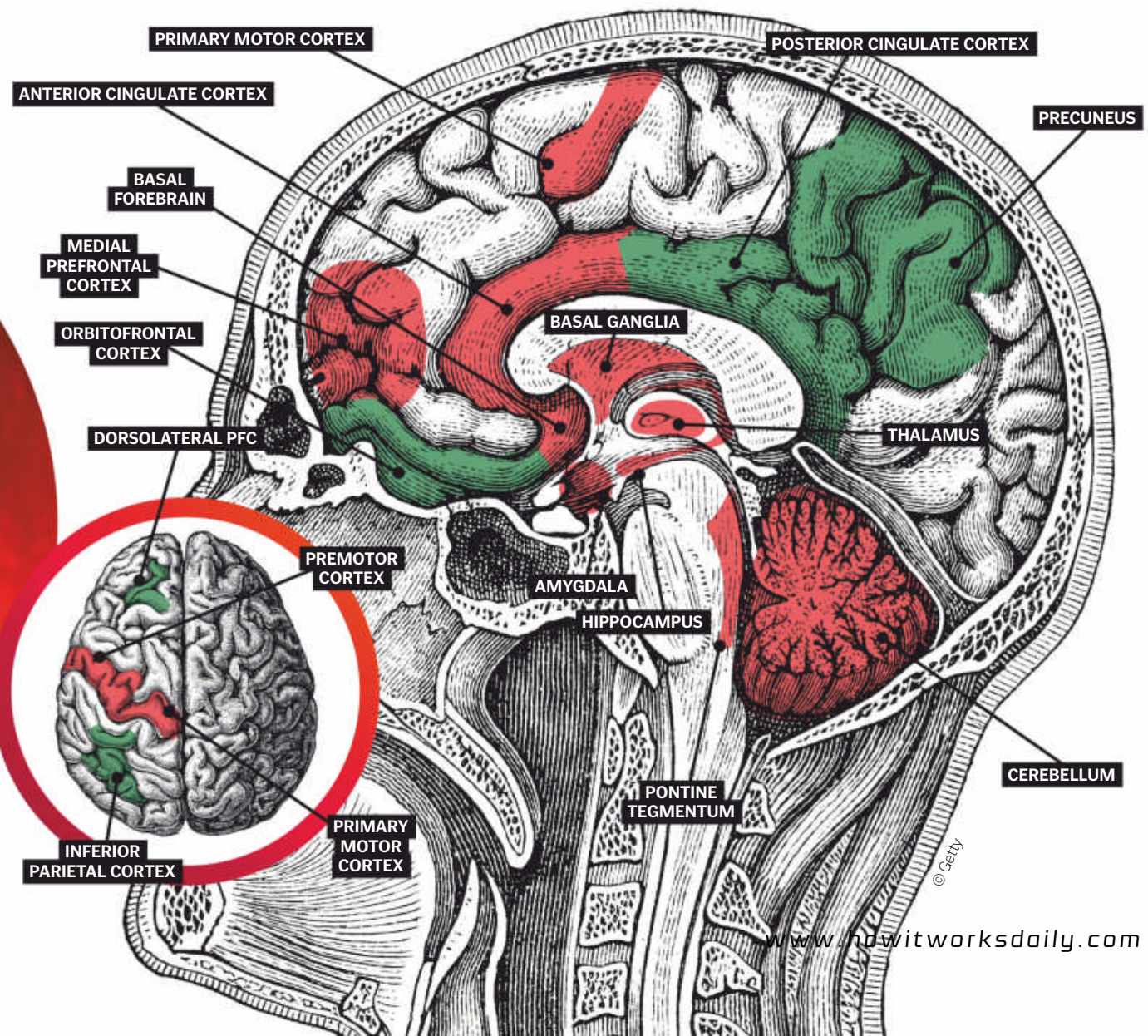
What regions of the brain are awake while we dream?

Activated

There are several regions of the brain that are active during REM sleep which have different roles when considering their functions while dreaming. Regions such as the cerebellum, basal ganglia and premotor cortex are linked with the motor content of our dreams. These regions are responsible for creating the sensation of movement, like running from an intruder during a nightmare. Other regions such as the thalamus and basal forebrain are linked to the emotion-processing aspects of our dreams.

Deactivated

While many regions are activated to produce dreams and nightmares, some are deactivated to allow them to occur. For example, regions of the prefrontal cortex and inferior parietal cortex are typically involved in cognitive control, perception of time and space and self awareness. This allows us to drift off into a dream unaware of our physical bodies. The deactivation of these regions is also thought to contribute to the reason we don't often remember our dreams when we wake up.



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Inside the venom

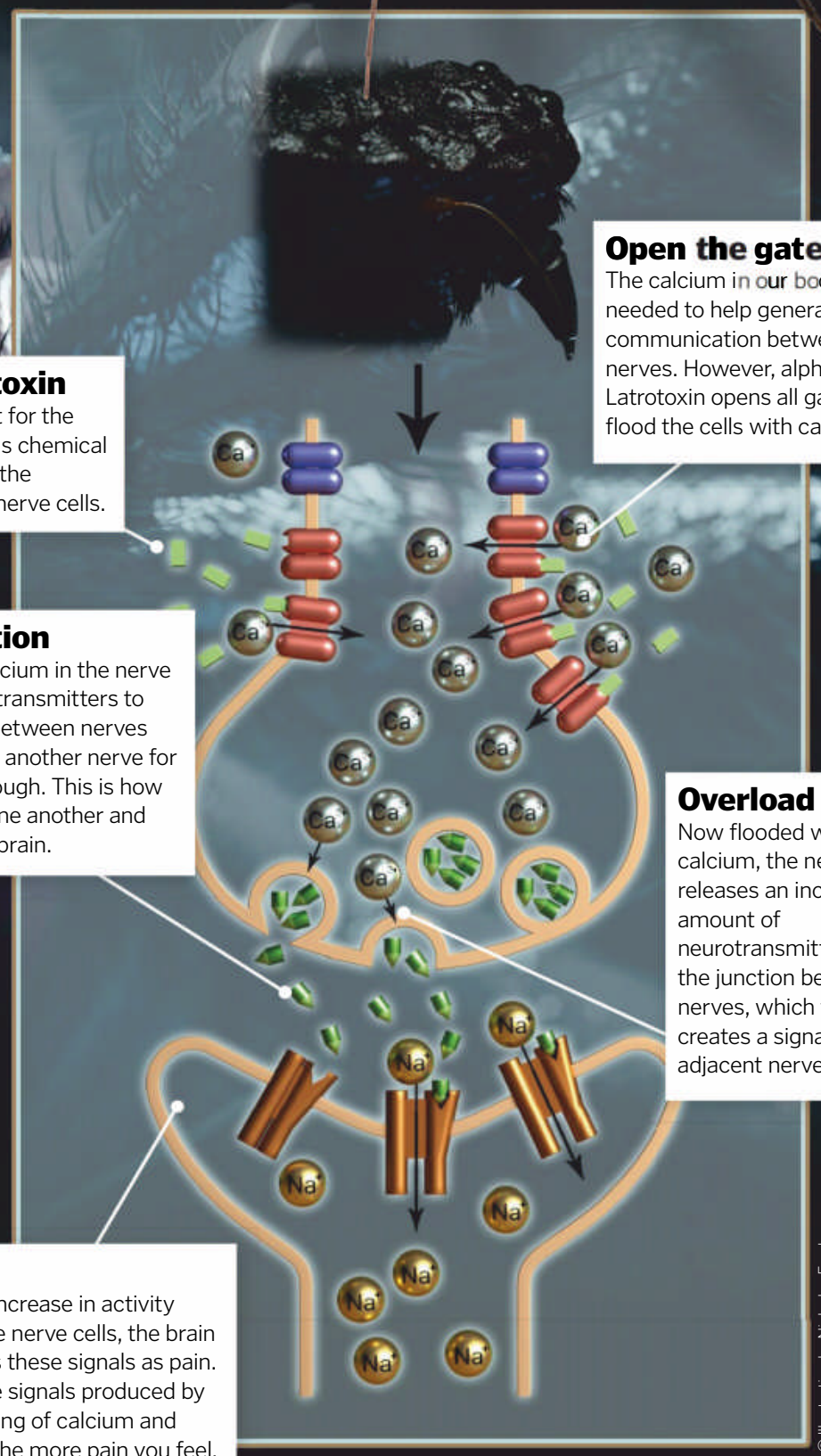
How black widow venom causes excruciating pain

Venom gland
Venom is produced and stored in a small sack at the front of the spider's head.

Alpha-latrotoxin
As the main culprit for the causing of pain, this chemical embeds itself into the membrane of our nerve cells.

Communication
The presence of calcium in the nerve cells triggers neurotransmitters to cross the junction between nerves and opens gates on another nerve for sodium to pass through. This is how nerve cells talk to one another and send signals to the brain.

Venom canal
When the spider is threatened the venom will travel from the venom gland, down the venom canal and into the fang, passing into its victim.



Open the gates
The calcium in our bodies is needed to help generate communication between our nerves. However, alpha-Latrotoxin opens all gates to flood the cells with calcium.

Overload
Now flooded with calcium, the nerve releases an increased amount of neurotransmitters in the junction between nerves, which then creates a signal in the adjacent nerve.

Pain
With an increase in activity within the nerve cells, the brain perceives these signals as pain. The more signals produced by the flooding of calcium and sodium, the more pain you feel.

© Illustration by Nicholas Forder

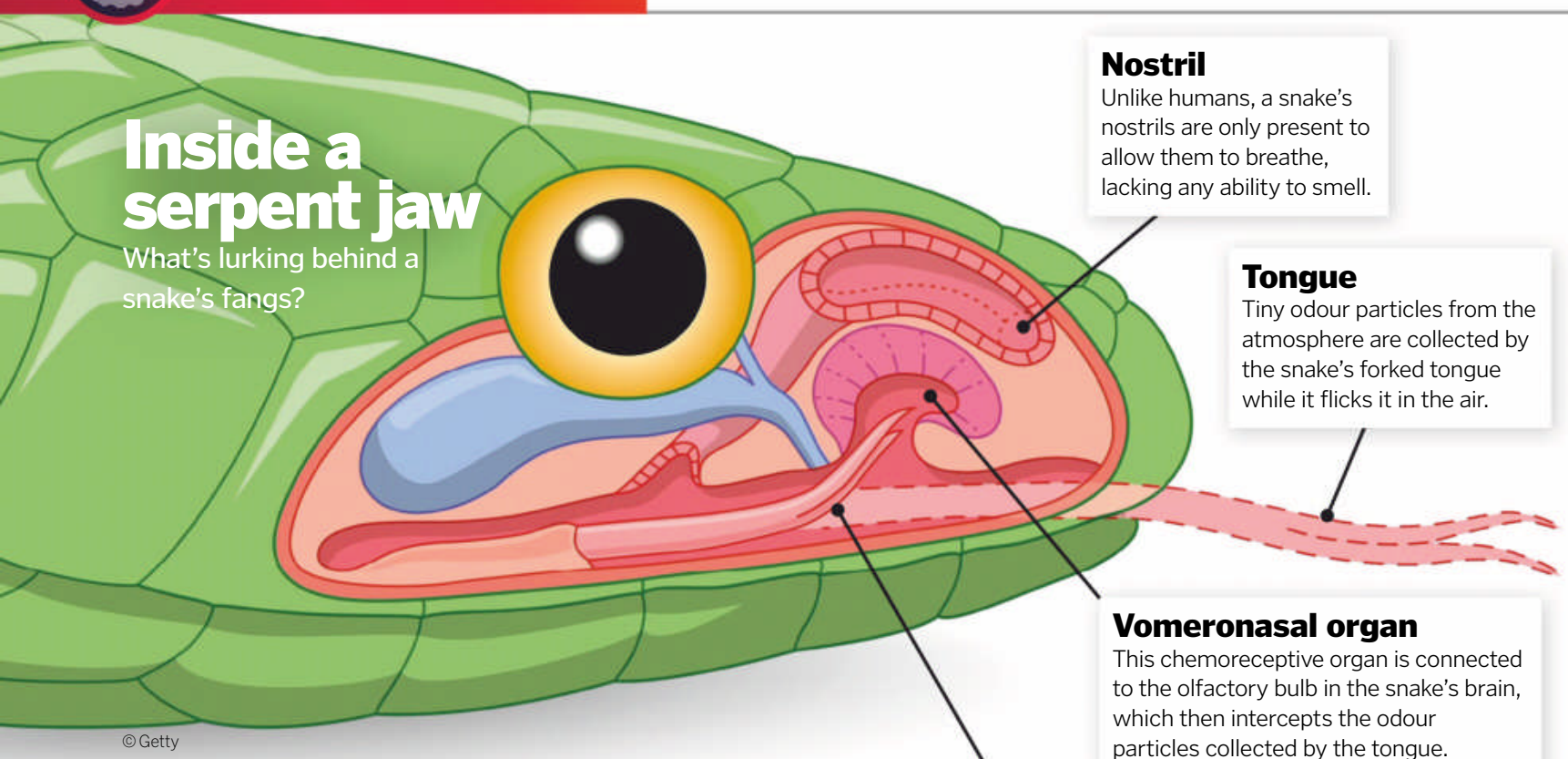
WHY IS BLACK WIDOW SPIDER VENOM SO POTENT?

Striking fear into the hearts of those that spot the tiny red markings on an otherwise ordinary-looking spider, black widows are some of the most venomous creatures on Earth. This accolade has led to many believing this spider to be an aggressive insect. In reality these spiders are shy and they only attack humans when their bodies have been pinched or accidentally squashed.

However, when they do strike it wreaks havoc on the human nervous system. What makes their bite so agonising is the presence of a neurotoxin called alpha-latrotoxin. This neural hijacker causes rampant pain throughout the victim's nervous system. However, it's a common misconception that a single bite from a black widow spider is always a death sentence. Fatality is rare in healthy humans, with most recovering with medical assistance in 24 hours. Young children and those who are ill or elderly are at the highest risk.


© Getty

Black widows are found in temperate regions around the world



Inside a serpent jaw

What's lurking behind a snake's fangs?

© Getty

WHY IS A SNAKE'S TONGUE FORKED?

It's all to do with the way these reptiles observe the world around them. The flicking of a serpent's forked tongue might seem intimidating at times, but they are simply tasting the air. While we use our noses to smell and our tongues to taste, snakes gather chemicals that pertain to smell and taste from the atmosphere and interpret them. Unlike the human tongue, snakes lack the many taste buds we've come to rely on. They have instead evolved a sensory organ called the vomeronasal, or Jacobson's organ, to detect moisture-borne odour particles. This has two holes – corresponding perfectly with the forked ends of the tongue – which collect the particles and deliver them to the vomeronasal organ as the snake flicks its tongue. The reason snakes do this is to detect the location of any potential prey, catching the scent of a nearby mouse in the wind or even the presence of a predator or potential mate.

Typically a snake flicks its tongue once every second, if not faster

© Getty

IS YOUR PHONE EAVESDROPPING ON YOU?

It seems oddly serendipitous when, after a conversation, online ads begin recommending brands of products you may have discussed. Is it a coincidence, or is your phone secretly listening to you? Facebook has repeatedly stated that its app does not listen to users for ad-targeting, though some sources report that many apps have permission to activate our microphones and the ability to analyse snippets of audio. In the grand scheme of things, however, listening in on our conversations for targeted ads isn't the most effective method to get relevant information – especially when you consider the wealth of information our digital footprints can provide, such as what we view, like or share on social media, or the cookies gained from our Google search history. It's far more likely that your previous online activities, a tweet or Facebook post has sparked an ad.

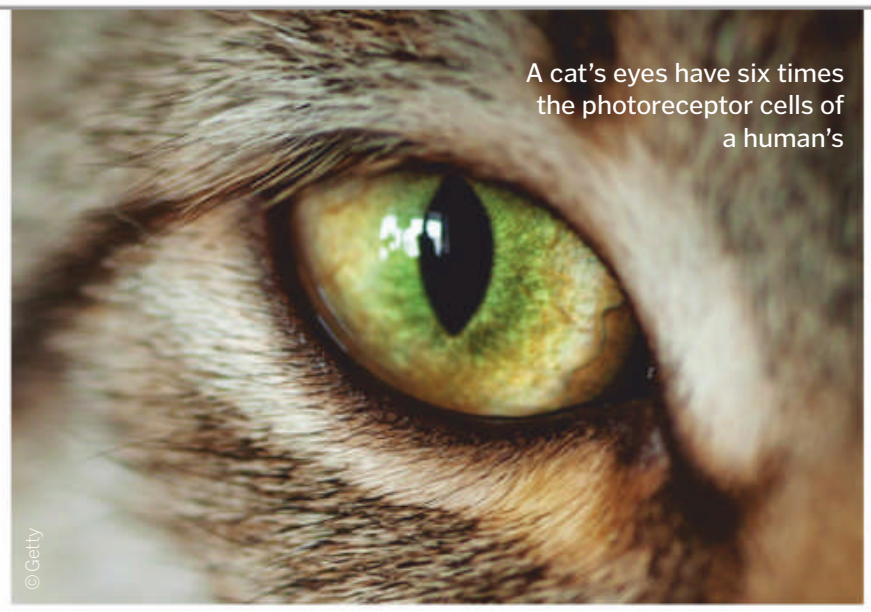
WHY DID THE AZTECS SACRIFICE HUMANS?

Standing over a stone altar at a temple summit, an Aztec priest raises his obsidian blade before plunging it into the chest of the body laying before him, allowing the blood of the human sacrifice to cascade down the temple steps. It's a scene well documented throughout history when you delve into the traditions and rituals of the Aztecs, who lived between the 14th and 16th century.

Many Spanish conquistadors recorded seeing such bloodthirsty rituals, and even detailed a rack of 130,000 skulls of the victims called a tzompantli. It wasn't until 2015 that this enormous and terrifying edifice was excavated by archaeologists, revealing the secrets of human sacrifice. It's thought that humans were offered as nourishment to the Aztec gods to ensure that the Sun would rise and to allow prosperity for the people. Those that evaded the sacrificial altar were not the only ones thought to prosper from sacrifice. Those that felt the sharp edge of the knife were believed to gain an honoured place in the afterlife.

© Getty

The skull rack found during the excavations of the Aztec Templo Mayor, Tenochtitlan



A cat's eyes have six times the photoreceptor cells of a human's

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WHY ARE CAT PUPILS VERTICAL?

As fierce hunters, cats and other nocturnal predators have evolved vertically slit pupils as a way to better ambush their prey at night. To successfully seek out their prey, cats need to be excellent at gauging the depth and distance of their next meal. This is where having a vertical pupil comes in handy. Researchers have found that predators such as snakes, cats and crocodiles are better at depth perception and can easily focus on their targets.

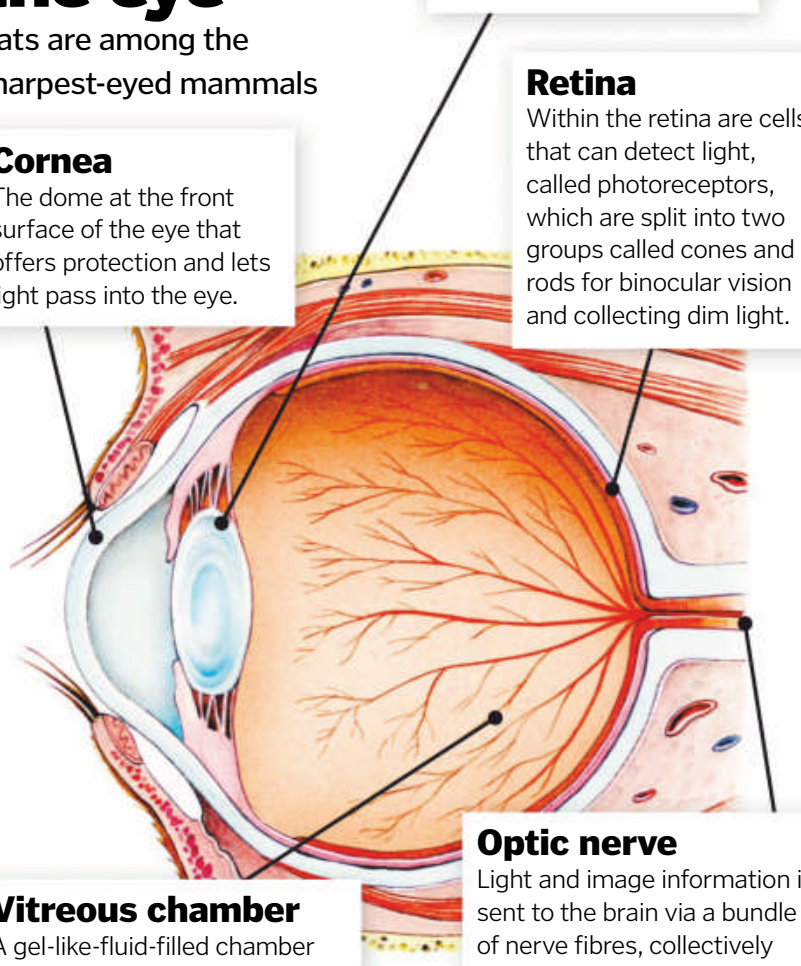
Look inside the eye

Cats are among the sharpest-eyed mammals

Lens
The lens changes shape to focus light into the retina.

Retina
Within the retina are cells that can detect light, called photoreceptors, which are split into two groups called cones and rods for binocular vision and collecting dim light.

Cornea
The dome at the front surface of the eye that offers protection and lets light pass into the eye.



Optic nerve
Light and image information is sent to the brain via a bundle of nerve fibres, collectively called the optic nerve.

Vitreous chamber
A gel-like-fluid-filled chamber maintains the shape of the eye.

© Getty

WILL THE SUN ENGULF EARTH?

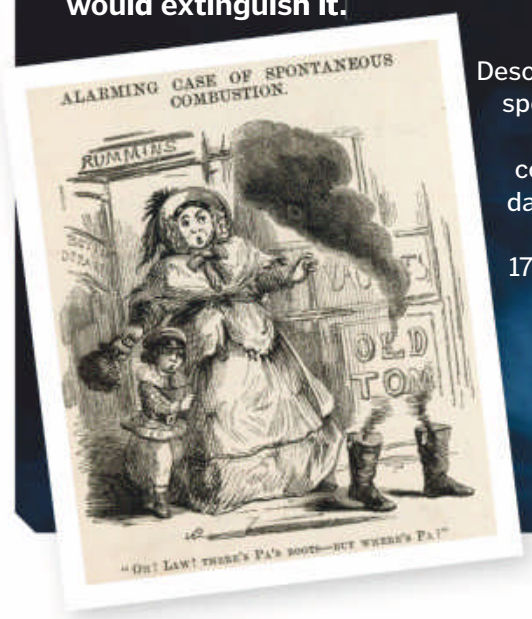
© Getty

As our Sun expands towards the end of its life, the planets in its path will ultimately meet their doom. Earth is in the firing line, but not for a long time. In around 5 billion years the Sun will start to swell into a red giant, engulfing Mercury and Venus, then Earth. However, long before it swallows our planet, the heat generated from the giant fireball will boil the oceans and kill all life on Earth. In around 7.5 billion years the Sun will have used up 33 per cent of its current mass, weakening its gravitational hold on Earth and sending our planet into an expanded orbit. This may not be enough to save Earth, with many physicists predicting it will meet the same fate as Mercury and Venus.

IS SPONTANEOUS HUMAN COMBUSTION POSSIBLE?

The idea of spontaneously erupting into flames without any prior warning is a harrowing concept, but luckily it's one unsubstantiated by science. As a prevalent theme in fiction during the 1800s, novels such as Charles Dickens' *Bleak House* brought forth the terrifying idea that at any time one of us might suddenly ignite and perish.

Following this idea were claims of real-life occurrences. However, only a handful have ever been formally investigated. Each incident involved elderly victims whose remains were found near open flames such as candles or smoking cigarettes. The fatal flaw in the idea of spontaneous human combustion is in our biology. The human body is made up of 60 to 70 per cent water, a natural enemy of fire. If an internal fire should ignite, our bodies would extinguish it.



Descriptions of spontaneous human combustion date back as far as the 17th century

© Alamy

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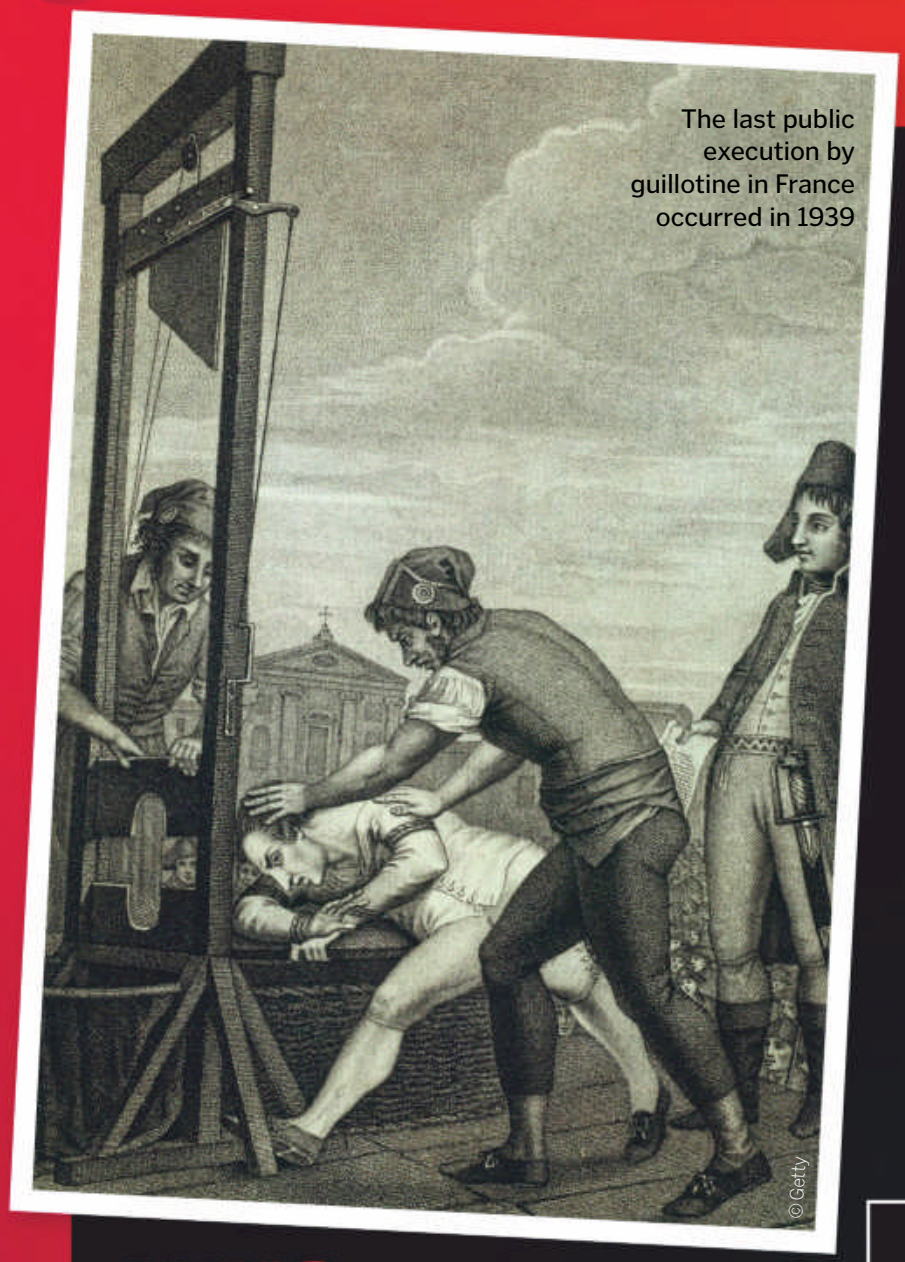
WHAT IS DARK MATTER?

Looking out into the abyss of space might leave you wondering why the universe is dominated by darkness. It's believed that the universe is made up of roughly 80 per cent dark matter, a mysterious material which does not emit energy or light.

Although we aren't sure what it is made of, leading the pack as a potential candidate are weakly interacting massive particles (WIMPs), which have a hundred times the mass of a proton but are extremely difficult to detect.



The last public execution by guillotine in France occurred in 1939

© Getty

WHO INVENTED THE GUILLOTINE?

It may surprise you to discover that anatomy professor Joseph-Ignace Guillotin proposed the guillotine as a gentler method of execution. Guillotin believed that swift decapitation by a blade would be more humane than a sword or axe swung by an executioner. The first life to be officially claimed by a prototype guillotine occurred in France in 1792, designed by French doctor Antoine Louis.

This new form of execution was given the name guillotine after Guillotin's recommendation. However, it's believed that he was against capital punishment and was horrified by the device's name. The guillotine was used until 1981 when the death penalty was abolished, during which time it became a major spectator event and was deemed high entertainment, with souvenirs sold at executions and programmes listing the names of those being executed that day. The guillotine even became a popular children's toy, while novelty devices were sold as vegetable and bread slicers.

Behind the blades

How does a guillotine work?

Wheels
Between the rope and the wooden frame, a series of wheels allowed the executioner to release and raise the blade.

Blade
Made from steel, the angular blade had serrated edges. Together with the mouton, it weighed around 40 kilograms.

Mouton
A piece of metal that secured the blade in place and offered extra weight to drive the blade as it fell.

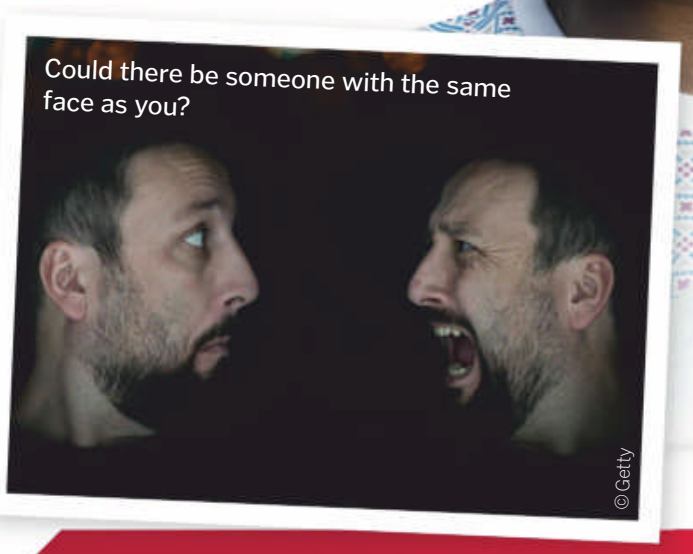
Restraint
The victim was held between two wooden slats, called a lunette, to secure the head in place.

Declic
This is the lever the executioner would pull to release the blade, to decapitate the victim.

© Illustration by Adrian Mann

IS SOMEONE OUT THERE WEARING YOUR FACE?

With over 7 billion people on the planet, there is surely going to be someone that shares enough of our facial features to be deemed our doppelganger. We seem to have an odd fascination with finding them and alerting others to their existence: "I saw your double in the supermarket the other day." However, the chances of actually finding one are relatively slim. A 2015 study found that there is a one in 135 chance that someone shares enough facial features to be deemed a doppelgänger. The figure was calculated by comparing eight distinct facial features of 4,000 different people. Researchers found that finding a doppelganger with all eight matching features was a one in a trillion chance.



Could there be someone with the same face as you?

© Getty

COULD A SCREAM BE HEARD IN SPACE?

In the vast vacuum of space, the sound of a lone scream isn't something that can be heard. Not just because the human body would erupt if exposed to space, but for sound waves to travel they need a medium – solid, liquid or gas – to move through. For example, when the skin of a drum is struck, vibrations cause a chain reaction of moving air molecules, pushing them together and creating a sound wave. In space no such medium exists. That's not to say that sound can't travel through space at all – it can, but very inefficiently – so if you find yourself screaming in space, no one will hear you.

© Getty

Sound needs a medium to travel through

5 FACTS ABOUT FAMOUS PRISONERS OF THE TOWER OF LONDON

Source: Wiki/ XXXX

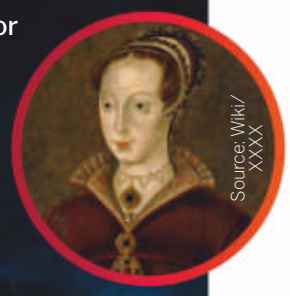
1 Anne Boleyn
King Henry VIII's second wife was imprisoned at the tower, falsely accused and convicted of adultery, incest and treason. On 19 May 1536 she was executed, beheaded by the blade of sword.

Source: Wiki/ XXXX

2 Guy Fawkes
As a chief conspirator in a plot to blow up parliament, Fawkes met his end on 31 January 1606 after being imprisoned in the tower. As he was walking onto a hanging platform, Fawkes jumped from the ladder, breaking his neck and dying.

Source: Wiki/ XXXX

3 Queen Elizabeth I
Queen Mary I believed Princess Elizabeth was plotting against her, ordering her incarceration in 1554. A lack of evidence for Mary's theory resulted in her release after a couple of months.



Source: Wiki/ XXXX

4 Lady Jane Grey
She was queen for just nine days after her father-in-law John Dudley persuaded a dying King Edward VI that Jane should be chosen as his successor. Deposed by the legitimate heir Mary, her and her husband were imprisoned in the tower and executed in 1554.

© Getty

5 The Kray Twins
As the last prisoners in the tower, these London gangsters were notorious murderers and thieves. However, these were not the crimes that landed them in the tower, but for assaulting a corporal after failing to report for national service with the Royal Fusiliers.

White blood cells produce antibodies to target allergens

ALL ABOUT ALLERGIES

Sneezing, swelling and worse: what happens when your immune system goes into overdrive?

Words by **Ailsa Harvey**

Our bodies are constantly reacting to their surroundings. When it gets cold, your muscles work to warm you up. When you need food your stomach rumbles to alert you. When bacteria or viruses enter your body, cells instantly recognise them as harmful intruders to target.

The latter is performed by your immune system, a preprogrammed defence system consisting of organs, cells and proteins that is active throughout your entire body. As well as detecting threats to physical health, the immune system can sometimes become overactive, triggering an unnecessary response to non-toxic substances. This is how allergic reactions arise.

Every cell in your body has antigens. These are proteins that identify the cell and brand it as friend or foe. Our bodies use these to decide which cells to ignore and which to attempt to destroy or flush out of our bodies. An example of those that are usually ignored by the immune system are the cells of food products. We need food to remain in our body to provide us with energy and nutrition. But for some people this isn't always the case.

If you are allergic to an item of food, it won't take long to discover that your body doesn't welcome it. Your immune system will often first react towards the apparent invader when the allergen touches your mouth, likely causing you to feel pain or discomfort. Having wrongly identified a particular substance as a threat, proteins called antibodies are sent to locate the offender, attaching to it. When connected these antibodies act as a signal to other immune cells to show them where the danger is. During this process, histamine is produced. Histamine is the chemical responsible for the persistent symptoms you experience during an allergic reaction. The result of this chemical depends on the location it is released into.

Just as the allergen can vary enormously, so can the body's response. While some people's allergies are an inconvenience, for others they are life-threatening. One aspect that can make reactions so deadly is that to most

WHAT IS ANAPHYLAXIS?

Some people's allergic responses are a seasonal inconvenience, but for others they are much more dangerous. Allergies can be severe and even life-threatening when not managed and responded to hastily.

Anaphylaxis is a severe response to an allergen. One in 1,000 people may experience this type of reaction, where a sudden allergic reaction can escalate quickly. When the body reacts to the allergen, a surge of chemicals puts the body into shock. This can result in a drastic drop in blood pressure or narrowing airways – or both – and these can result in unconsciousness.

To manage symptoms of an anaphylactic attack, sufferers are injected with adrenaline. Anaphylaxis sufferers carry an epipen with them at all times, which they use to inject this drug as soon as it's needed. Without a quick response, it can be fatal.

© Getty

Epipens contain a drug which constricts blood vessels to reduce swelling and reverse an allergic reaction

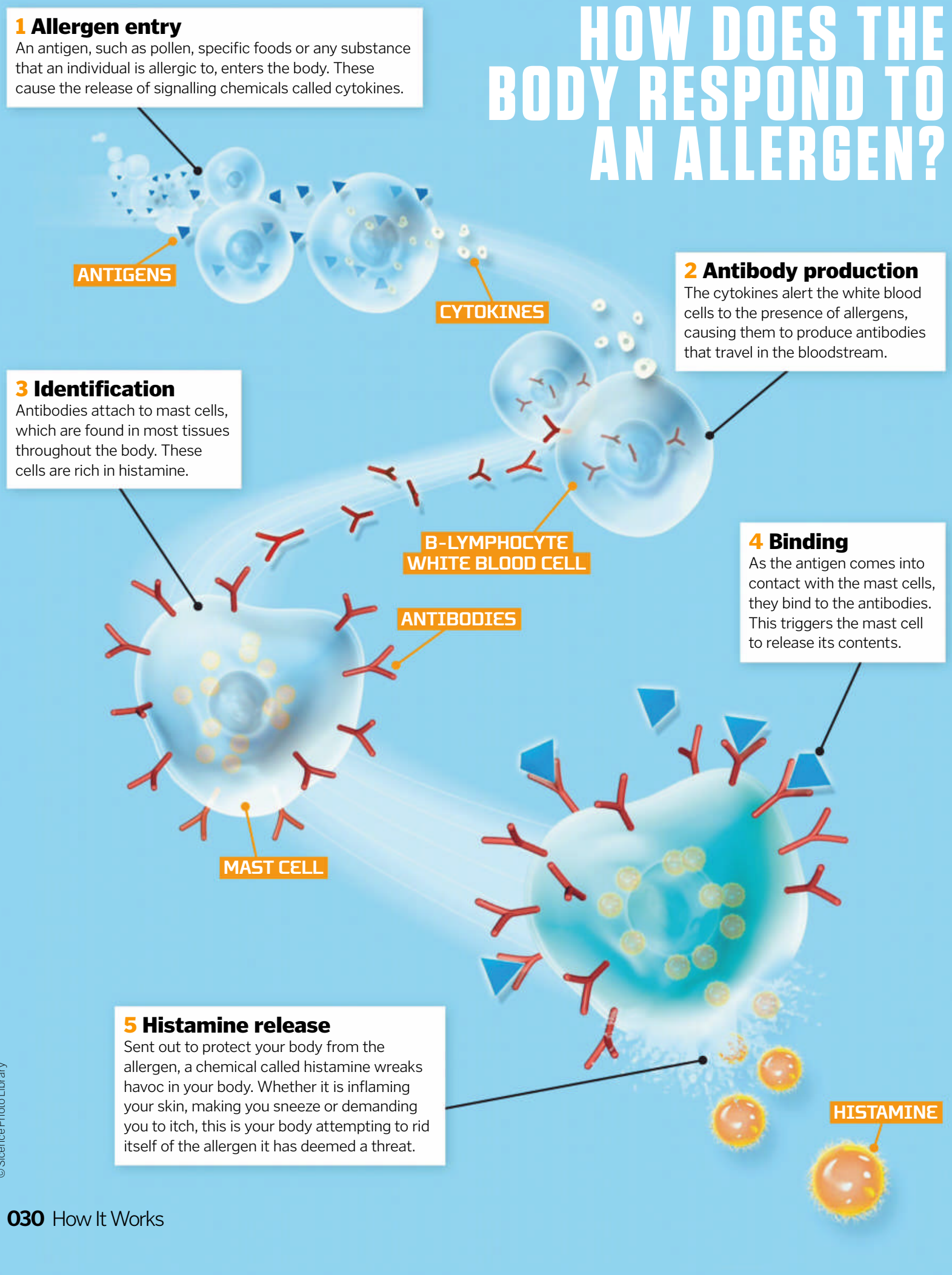
people, allergens are usually harmless. For example, to most of us peanuts are simply a food source. They can be found in a wide variety of packaged foods, and many people would choose them at a supermarket. Because the threat is not a universal one, those who could be killed by being in close proximity to the nut have to have their wits about them at all times. Their allergy is always at the forefront of their mind, and through habit it becomes their first thought before they choose a snack.

Some milder allergies produce similar symptoms to your average cold, including the common effects of a runny nose and puffy eyes, so how can you be sure that what you're experiencing is an allergic reaction? One way to spot an allergy is to look for patterns in the appearance of your symptoms. For instance, if you find that every time you go outside in the summer you begin to sneeze, this could be a seasonal hay fever allergy. Meanwhile, if you begin to feel itchy every time you play with your friend's dog, you are likely to have an allergy to its dead skin, saliva or urine – not its fur.

Our understanding of the science behind allergies has improved through research, but our complex immune systems are unique to every one of us. Even as early as the first century BCE, Roman philosopher Lucretius is quoted as saying: "What is food to one man is bitter poison to others." Luckily for today's allergy sufferers, there are ways to spot, diagnose and manage these anomalies in our bodies' defences and ensure that our immune systems, designed to save our lives, are less likely to do the opposite.

> *"While some allergies are an inconvenience, for others they are life-threatening"*

HOW DOES THE BODY RESPOND TO AN ALLERGEN?



1 Allergen entry
An antigen, such as pollen, specific foods or any substance that an individual is allergic to, enters the body. These cause the release of signalling chemicals called cytokines.

2 Antibody production
The cytokines alert the white blood cells to the presence of allergens, causing them to produce antibodies that travel in the bloodstream.

3 Identification
Antibodies attach to mast cells, which are found in most tissues throughout the body. These cells are rich in histamine.

4 Binding
As the antigen comes into contact with the mast cells, they bind to the antibodies. This triggers the mast cell to release its contents.

5 Histamine release
Sent out to protect your body from the allergen, a chemical called histamine wreaks havoc in your body. Whether it is inflaming your skin, making you sneeze or demanding you to itch, this is your body attempting to rid itself of the allergen it has deemed a threat.

© Sicence Photo Library

5 FACTS ABOUT UNCOMMON ALLERGIES

1 Money
Sometimes occurring days after handling coins, it's possible for money to trigger a response. This is a nickel allergy. Sufferers may also need to limit contact with jewellery, door handles and some metal accessories.

2 Water
This rare condition, called aquagenic urticaria, gives sufferers an itchy rash when water touches their skin. With water being essential to life and with no effective treatment, water allergies can only be soothed with medical creams.

3 Vibrations
Vibratory urticaria is a condition which makes someone respond to any vibrating movement with rashes, headaches and face flushes.

4 Exercise
Although people joke about being allergic to exercise, for some it's a reality. This ranges in severity, but rigorous movement can bring on anaphylaxis in some. In these cases any form of exercise shouldn't be carried out alone, and medical supplies need to be at hand.

5 Human touch
If you have dermographism, your body's reaction to touch can be so instant that you could write on your skin with just the light touch of your own finger. The exact cause isn't known, and so there is currently little treatment available.

ALLERGY TYPES

From our outer surface to internal organs, where does the immune system target?

SKIN IRRITANTS

There are multiple ways that your skin can react to a number of allergens, with different patterns, lumps and sizes of rashes. Skin is usually the first part of your body that everything in the outside world can reach. When your body doesn't agree with an antigen that has reached the skin, it will sometimes display its disturbance with a rash. The most common type of skin allergy is contact dermatitis. This is a type of eczema which causes the swelling, bumps and rashes that can instantly occur from contact with an allergen.

This rash of large bumps, called hives, most commonly occurs during food and drug allergies

© Alamy

Most food allergies are caused by these eight foods

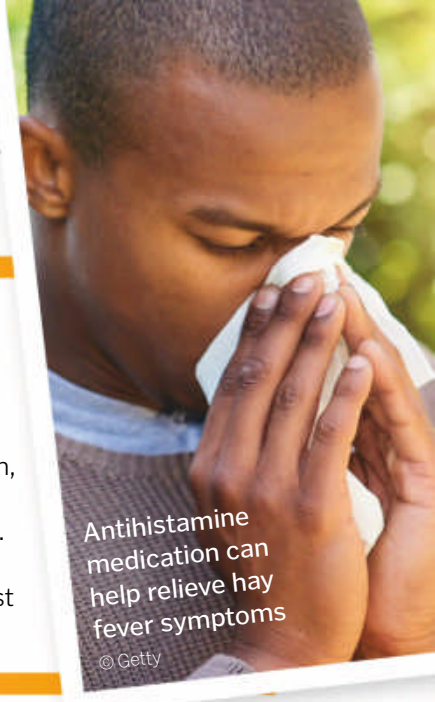
© Getty

FOOD

Food is essential for life, but for some people certain foods can pose a threat. 90 per cent of all allergic reactions caused by food are a result of consuming eggs, milk, peanuts, tree nuts, fish, shellfish, wheat and soy. Reactions to food allergens vary drastically, but they include swelling of the tongue, face and throat, feeling sick, abdominal pain and tingling in the mouth. These responses can begin within a few seconds of the food touching the person's mouth.

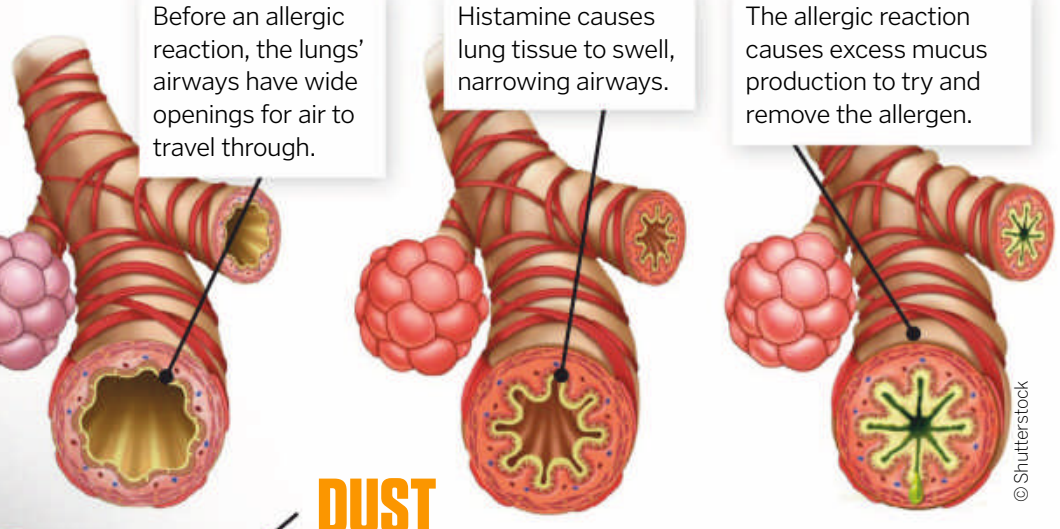
POLLEN

You can tell when summer is approaching from the warming weather. If you have hay fever, your body gives you other telltale signs. Your eyes begin to water, your nose starts to run, headaches become a common occurrence and your eyes, nose, ears and throat produce an aggravating itchy sensation. Flowers increase their pollen production as the summer season approaches, meaning that this seasonal allergy is most common between the months of March and September.



Antihistamine medication can help relieve hay fever symptoms

© Getty



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DUST

Inhaled allergies are the most common. Because the allergen is found in the air, it is often unavoidable and can easily enter the body. When breathed into the lungs of someone who is allergic, house dust, mould spores and proteins from animals can all irritate the airways of the lungs and induce asthma. This can make the individual wheeze, cough and feel breathless.

DRUGS

Medication is designed to help the human body, but each body is different. A drug that will cure one person could have adverse effects on another, with the most common signs being fevers and rashes. Antibiotics such as penicillin are the most common culprits, with up to ten per cent of people being told they have this allergy. A drug allergy needs to be documented on an individual's medical records.

© Alamy

INSECTS

When an insect bites or stings, redness and soreness are common. Some insects have defence mechanisms designed to cause you pain, so how do you know if your body's response to an insect's attack is standard or an allergic reaction? An allergic response is more severe, causing abnormal swelling or soreness. Often these are in other areas of the body away from the targeted area. If your face begins to swell up, you feel light-headed or you have difficulty breathing following a bite or sting, it is likely that you are having an abnormal reaction.

The immune system can overreact to the proteins in a mosquito's saliva

© Getty

HOW TO DIAGNOSE AN ALLERGY

SPOTTING THE SYMPTOMS

What are some of the main signs of an allergy?

Breathing difficulties

A tight chest and shortness of breath can be indications of an allergy. Your immune system can sometimes respond by narrowing your airways. This inflammation in the lungs can cause wheezing, restricting the air travelling through your lungs.

Sudden sneezing

It is common for allergens entering the nose to cause inflammation. This response, from the likes of pollen, dust and pets, affects one in five people in the UK. Sneezing and a runny nose can be your body trying to send the antigen back out from where it entered.

Swollen face

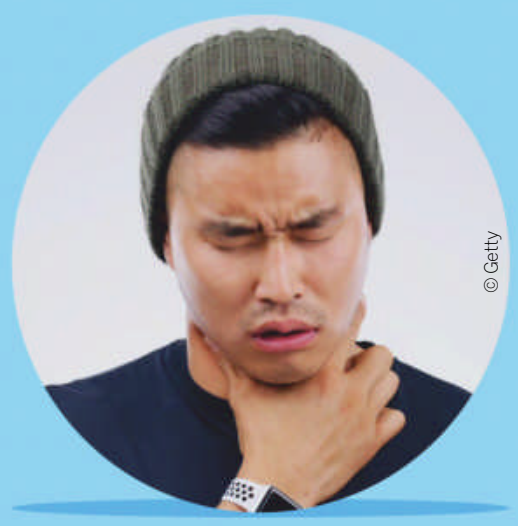
Your face can swell up for many reasons, with some caused by allergens. The skin around the eyes puffs up when the eyes are suffering from allergies such as allergic conjunctivitis. The face might swell after food reactions, drug allergies and during anaphylaxis.

Stomach pains

As part of some food allergies, a cramping stomach pain can occur immediately after eating the offending food. This is because histamine is released inside the intestines or stomach, commencing an attack on the allergen inside these organs.

Change in skin

As our outer layer, skin is our body's first chance to defend itself from danger. One common skin response to an antigen are hives. These are itchy and raised reddened areas of skin and could be an indication of a food, drug or insect allergy.



Closing throat

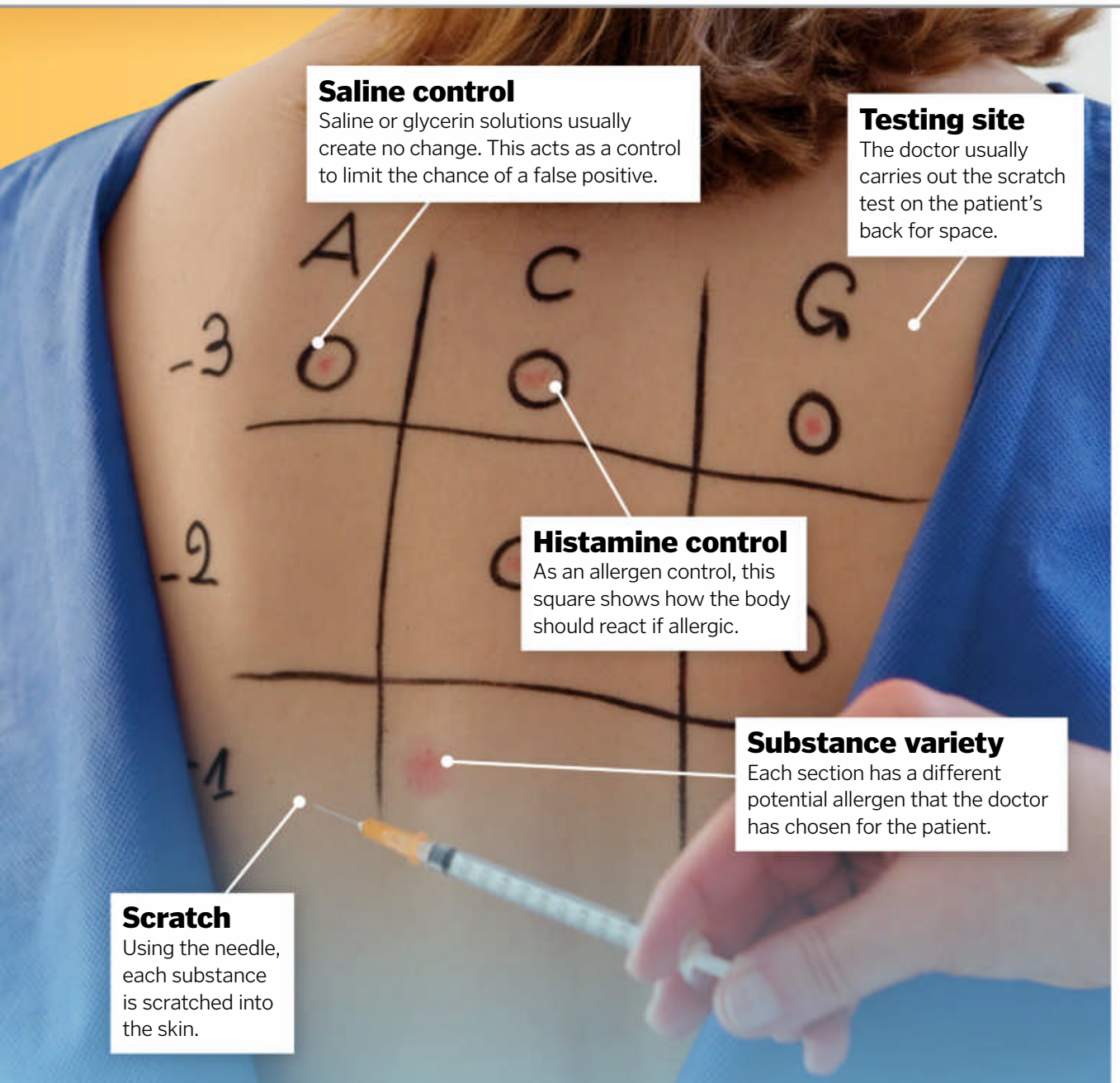
If your throat begins to feel tighter, this could be a severe allergic response. The feeling of a tight throat can range from it feeling swollen and sore to like having a band around your neck or an internal blockage, making breathing harder.

FOOD ALLERGY VS INTOLERANCE

How can similar reactions to food products be told apart?

ALLERGIC REACTION	INTOLERANCE
10%	**20%**
One in ten people are allergic to at least one food product.	At least twice as many people have a food intolerance.
FOOD ALLERGIES CAN OCCUR WITHIN SECONDS, SHOWING SIGNS WITHIN TWO HOURS	**IT CAN TAKE UP TO TWO DAYS FOR AN INTOLERANCE TO DISPLAY SYMPTOMS**
IMMUNE SYSTEM INVOLVED	**IMMUNE SYSTEM NOT INVOLVED**
Allergies occur when the immune system wrongly mistakes a type of food for a threat and tries to fight against it.	When the immune system is not alerted, the areas affected are more limited. Gluten intolerance is the only exception.
DEADLY TRACE	**VOLUME FLEXIBILITY**
Any amount of a food allergen can cause severe reactions – sometimes even being near the food.	Different people are able to consume different amounts before they show symptoms of intolerance.
HIGH RISK	**LOW RISK**
Severe allergies can lead to unconsciousness and become a risk to life.	Affected areas are limited to the digestive tract.
OVERACTIVE	**UNDERACTIVE**
The body undertakes extra and unnecessary work trying to fight off the allergen that it wrongly perceives as a threat.	Intolerances are often a result of a lack of enzymes to break food down. Without these the body is less active than it needs to be.

"Look for patterns in the appearance of your symptoms"



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DOCTOR'S DIAGNOSIS

You've spotted these symptoms and have gone to a doctor for advice. The doctor will have a good idea of whether you are suffering from an allergy or not, but in order to confirm it, they will carry out an allergy test. The most common is a scratch test, providing fast and accurate answers.

This test uses a patch of your skin to analyse the reaction towards potential allergens. A small drop of the allergen is placed on the skin and the surface is then scratched slightly to allow the allergen to get underneath a few layers. After about 15 minutes the doctor will be able to see which area swells up, and therefore which substance you are allergic to. If the allergy is not one which can be detected through a skin test, blood can be taken and analysed, but this will take a few days before the results are known.

MISDIAGNOSIS

Allergy symptoms can often overlap, sometimes making it difficult to be certain of what is causing the reaction. Some people are so eager to find a treatment for this irritation that they self-diagnose themselves incorrectly.

This often happens during the winter months, when chances of congestion increase. With the common cold closely imitating the symptoms of allergies, the two can be confused. In many cases self-diagnosis stems from sinusitis, which involves the sinuses swelling to produce pain in the face and congestion. Even medical experts have been known to get this wrong.

For those who have been given a false-positive diagnosis, sometimes it makes no difference. But sometimes the patient will avoid beneficial medicines such as penicillin, missing out on an antibiotic that is often the most effective cure. Others whose true allergens aren't recognised may continue to be exposed to the allergens that are causing their suffering. It's important to keep an eye on your allergies and seek further testing if you think you have been misdiagnosed.

© Getty

A misdiagnosis of a food allergy can compromise an individual's diet

AT-HOME ALLERGY TESTS

If you are worried that you are suffering from allergic reactions, seeking the help of a medical professional is the way forward. There are also some at-home tests that you can buy. These claim to be able to tell you your allergies by analysing a small amount of blood that you post to the laboratory.

Children usually need a medical professional to take their blood, but adults are just required to prick their finger and wait for their results. Although these tests have been shown to be a good indicator of some allergies, they actually only inform you of the allergens you are sensitive to by detecting levels of the immunoglobulin antibody. For a proper diagnosis, you then need to be tested through your doctor.

Home kits can be sent straight to a laboratory, where your blood is tested for antibodies
© Alamy

Why is Novichok so deadly?

How this toxic nerve agent affects the human body

Words by **Scott Dutfield**

Novichok nerve agents were developed in secret by the Soviet Union in the early 1970s, though deadly nerve agents have been around since the 1930s. It's believed that the initial development of these agents began as an alternative to insecticides. However, when their harmful effects on humans were discovered, this opened the door to a new potential use as chemical weapons. Nerve agents work by wreaking havoc on the nervous system. By disrupting the way nerves communicate with each other, Novichok can cause severe health issues that often result in death.

Nerves talk to one another by releasing a neurotransmitter called acetylcholine, which travels from one nerve cell to another across a synaptic junction. This is also how they talk to muscle cells. The acetylcholine binds with a muscle cell, signalling it to contract and creating movement. During normal cellular conversations, once the acetylcholine has reached a nerve or muscle cell it is broken down by an enzyme called acetylcholinesterase. Without this enzyme, acetylcholine would continue sending messages to more and more cells, a fact that Novichok exploits. When poisoned with Novichok, the acetylcholinesterase is prevented from breaking down the neurotransmitter, which accumulates. This leads to a constant contraction of the muscles, causing paralysis and convulsions and also preventing normal breathing from taking place. Symptoms can occur quickly - within 30 seconds of being poisoned in some cases – which include foaming at the mouth and hallucinations. There is an antidote to help prevent damage to the body, called atropine, but it must be administered quickly to prevent irreversible damage.

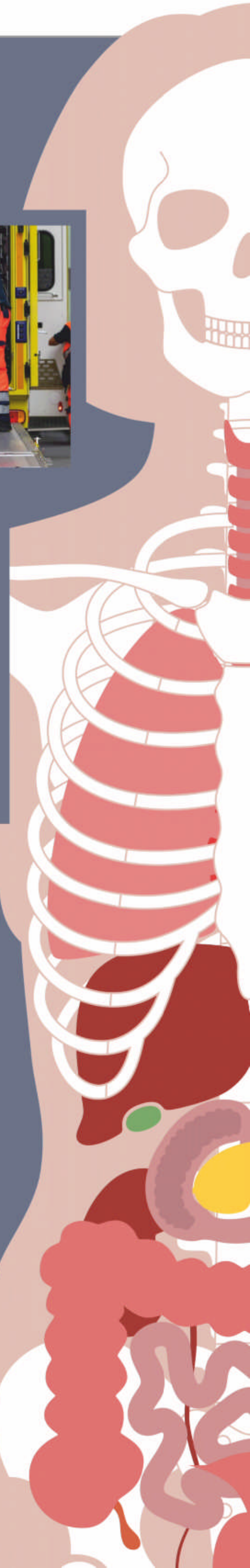
The deadly toxin can poison a person through inhalation, ingestion or even absorption through the skin. It is also spread through touch. At room temperature Novichok remains an ultra-fine powder or liquid and doesn't easily evaporate. Simply touching the nerve agent or coming into contact with someone who has touched it can transfer the poison. It's these qualities that led to the poisoning of a Russian ex-spy and his daughter in 2018 in Salisbury, UK. The pair were found stiff and unconscious on a park bench after coming into contact with the nerve agent, which was later found on their front door. This also resulted in a policeman investigating the case becoming poisoned with Novichok after touching the handle to the door.

There is still little scientific data on Novichok. Much more information is needed to understand exactly how long it lasts and also how many variations of Novichok's chemical structure there are.


© Getty

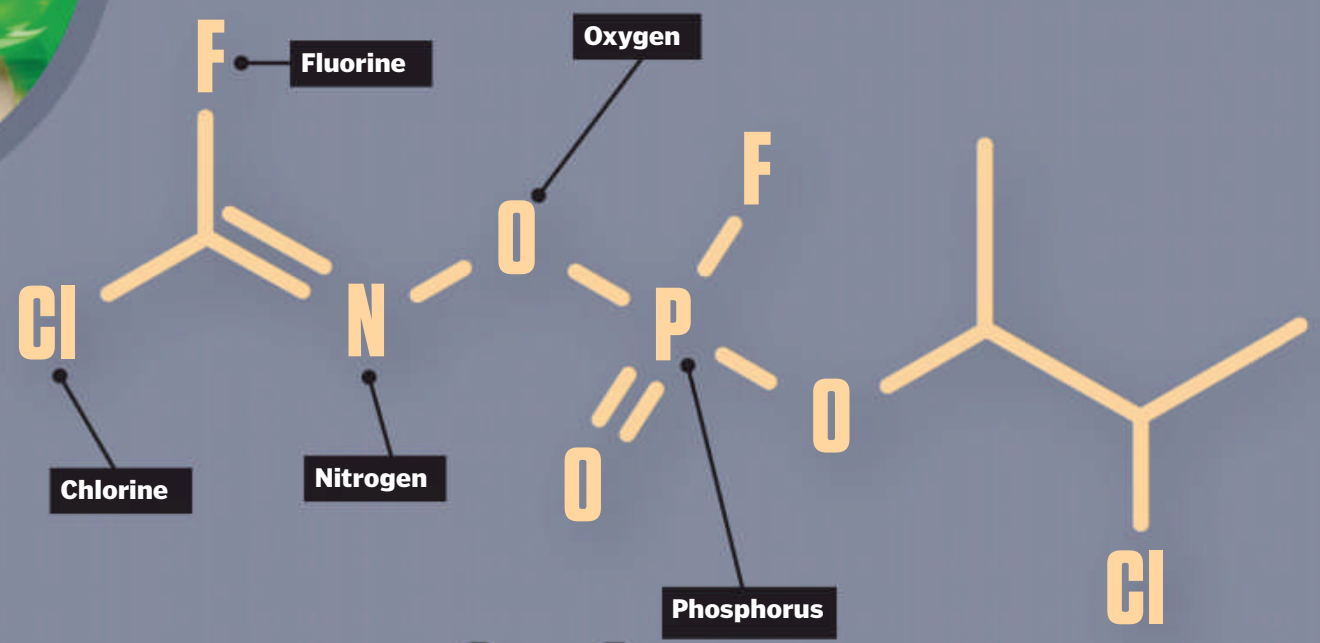
Earlier this year Kremlin critic Alexei Navalny was poisoned with Novichok, falling into a coma for a month before awakening

This is the isolation unit used to transport Alexei Navalny to hospital, preventing anyone else from coming into contact with the toxin



"Nerves talk to one another by releasing a neurotransmitter called acetylcholine"

Understanding Novichok



Novichok poisoning symptoms

What the nerve agent does to the body

Lungs
Rapid breathing and chest tightness, restricting air to the brain and leading to loss of consciousness.

Heart
Increased, rapid heart rate and blood pressure.

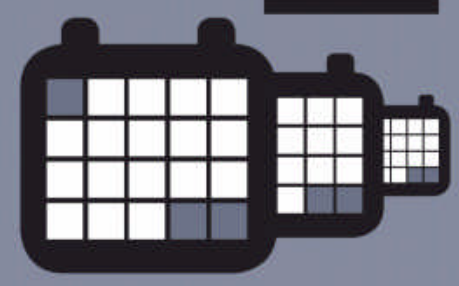
Muscles
Muscles go into overdrive, causing the body to convulse while also making muscles contract, causing paralysis.

Skin
Excessive sweating and muscle spasms at the site of infection.

Digestion
Nausea, vomiting and increased urination and diarrhoea.

© Getty

10 milligrams per person
is enough to be lethal through skin exposure

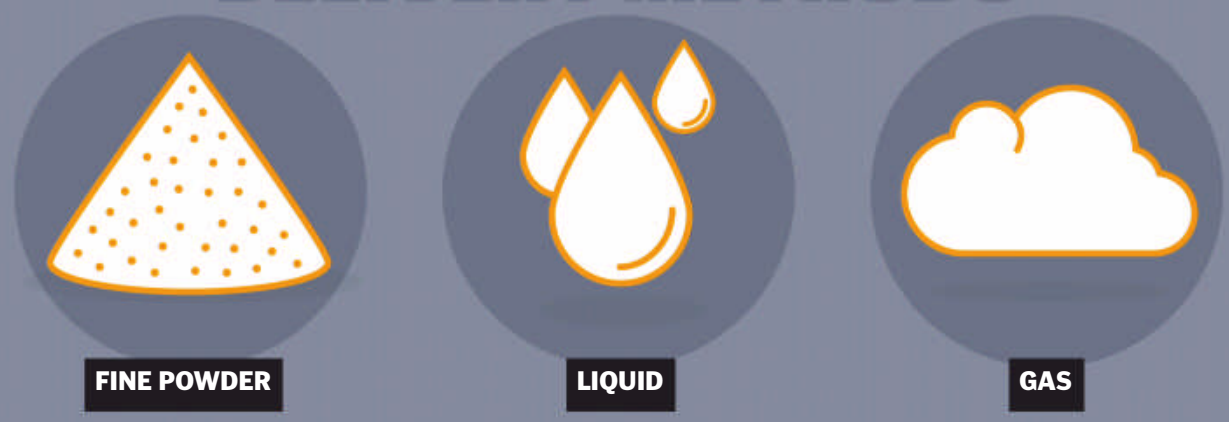


Experts believe Novichok can remain toxic for months or even years when kept in containers

30 seconds
Symptoms of poisoning can appear very quickly

5 to 8 times
Novichok is deadlier than VX, another potent nerve agent

DELIVERY METHODS



Samples can be dispensed into plates by hand or by robots

© Getty

© Beth Cole

© Ben Galley

INSIDE A CORONAVIRUS TEST LAB

Meet two scientists from the UK's COVID-19 megalab, working around the clock to test the public

At the beginning of lockdown, virologist Ben Galley and neuroscientist Beth Cole were forced to stop all their practical work for their PhDs – but that wouldn't keep them out of the lab. Because of their laboratory experience they were asked to work on COVID-19 test samples, analysing swabs sent in by the public. During April and May, Ben and Beth swapped their smaller Leeds-based labs for a new COVID-testing 'megalab' in Milton Keynes.

What was the experience like for you?

Beth: It was probably one of the most intense experiences of my life. It was good to be there and I was really happy that I was helping, but by the end I had to leave. The atmosphere and other people working there made it a good experience.

Ben: I really liked the sense of community. We were all there because we wanted to help. Although it was hard, it was nice that everyone was there wanting to do something good.

What did the training involve?

Beth: We were meant to have a few days of training on each step, but because we started during a final push towards reaching 100,000 tests a day, they were really trying to get it off the ground. We were chucked in the deep end and trained on the job. In the first few days we tried all the stages. After the training, people knew what they liked, and the person in charge quickly identified which roles we were best at. I was quite fast at the first step and ended up staying there for ages.

Ben: First we had an induction day to get used to the environment and the setting. Then we would be trained in each stage of the process, with someone shadowing you and showing you how to do it. A lot of the jobs are repetitive, so there's not so much of a learning curve. Over the course of a 12-hour shift, you end up being pretty good.

How much pressure was there to meet a daily target?

Beth: I found that the pressure was more external, coming from the news and the government. The people at the testing centre had more of an attitude of 'if you do it you do it'. They just wanted us to get as many tests done as we could.

Ben: Our boss was very results driven. That's important for the situation we were in, but it was very much that you had the minimum break, and often it was less than the minimum break. You would have to dash out, have a drink and come straight back. A 12-hour shift with no real break was very hard.

How many tests did you process in a day?

Beth: When I was on the first step, inactivating the virus, I had 94 samples on each plate, and it took between an hour and an hour and a half to do one plate. The most I ever did was around ten plates in a day. On my shifts we did around 20,000 tests. Milton Keynes was the biggest testing centre in the country, so our lab was a big chunk of the daily totals. The scientific process itself was quite fast, so I think the main delay in receiving results came from delivering the tests to the centre and then sending the results back.

What did your role involve?

Beth: We switched around stages, but I spent a lot of time on the first step, inactivating the virus. I opened the sample tubes and put the contents on a testing plate. This step could either be done by hand or by robots. I didn't really use the robots, but by the time I left they had doubled the number of robots to make things faster.

A day in the life of a COVID lab scientist

An average day shift at the UK Biocentre

07:30–08:00 Team breakfast

The 50 people working on the day's shift arrive from their hotel at around 07:30, where they are given breakfast to fuel the work ahead.

08:00–08:10 Morning meeting

The team finds out how many test deliveries they have been sent and are given an analysis of the previous day's shift. They can also talk through any problems that arose.

08:10 Assume positions

A whiteboard details the positions of everyone on the shift. As soon as they see their name and job, the lab workers make their way to their area and handover from the person finishing.

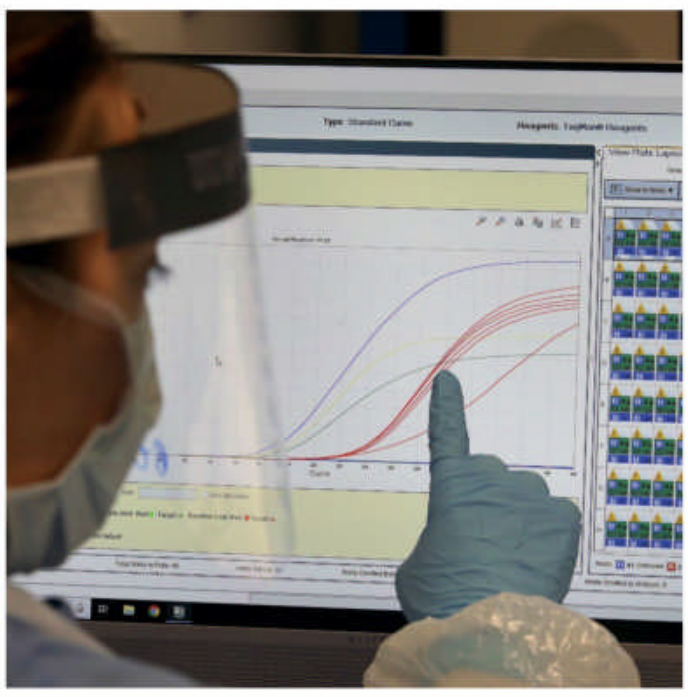
"Although it was hard, it was nice that everyone was there wanting to do something good"

While the robot was doing the work, you would always have to keep up with it, make sure all the lids were off and set up the tubes in place. You worked at the robot's speed, so it was manic.

Ben: We spent a lot of time on one particular process, but we were able to do all of them as they needed to make sure if people left, or became ill, they could slot another person into that role and it wouldn't slow down.

How accurate do you think the tests are?

Beth: As time goes on they will definitely be getting more accurate, but when I was there they were still finding their feet with how the tests worked and what the good controls were to include. I don't know the percentage error at the moment, but when I was there I think it was a 30 per cent error rate. That's fairly high, but you have to remember that in normal science you do everything at least three times, whereas there you have one go at it. I do PCR tests a lot, and the threshold would usually be pretty high. But in this circumstance it was low because they wanted to account for any detection of the virus. There are a lot of factors that can influence a test, and I think when you do a test you should take it with a pinch of salt. You should question a negative result if you know you have symptoms.


© Getty

Computerised graphs show the amplification growth of positive samples after testing

How different was this lab to the one you usually work in?

Beth: The main difference was that the implication of everything I did was a lot bigger. When I'm in the lab in Leeds, if I mess up it just gives me more hours of work, but in the COVID labs, that's a person's sample. Especially when it was whole care homes, you wanted it to be right. There's only one sample for each person, so you have to get it right the first time or that person has to do the test again, and I think it's quite a traumatic test.

Ben: You were very much a cog in the wheel. You were part of a process that worked, so you didn't have to improve it. Normally in a research setting I'm often tweaking it. If I do a practical and something isn't right, I can change it. That's a big thing in science, and I know a lot of people struggled with not being able to do that.

Was there anything that surprised you about the megalab?

Beth: There was no PPE a lot of the time when we were all together. We had to wear PPE when we were handling the virus samples, but because we had to work really close together there was less focus on socially distancing with each other. I was surprised with how little thinking I was required to do. I remember thinking 'what if I don't know enough?' and 'what if I'm completely out of my depth?' but we just had to use manpower. I had also never seen such a big-scale operation, because I had always worked in really tiny labs.

Ben: The application said that you would need a lot of experience, but I met one person who started who was a college student, and she didn't even know how to pipette. That's no insult to her, because I didn't know how to pipette when I was a college student, but you don't expect a college student to be in a diagnostic laboratory working on the coronavirus. It was quite startling. I think that was a rarity though, and I like to think that when they started hiring people full-time they


12:00 – 13:00

Lunch break

This is the lunch slot for some of the workers, but to make it a continuous process, not everyone can stop working at the same time.


18:00

Evening meal

The length of this break varies, but it usually involves eating and returning straight to the job. The boss of the lab also reveals how many samples have been processed so far.


20:00

End of shift

The night-shift group take over. After leaving the lab, the team need to isolate themselves in the hotel until they return to the lab again.

TESTING FOR COVID-19

1 Receiving samples

Samples taken from patients' noses and throats are placed in a tube with half a teaspoon of liquid.


© Getty

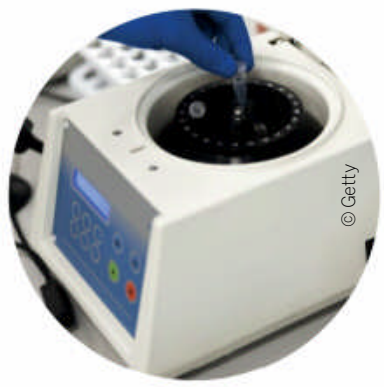
2 Inactivate the virus

Sample tubes are opened and put into a plate with a lysis buffer. This is a chemical which breaks down any virus in the sample, making it safe while still detectable.

© Getty

3 RNA extraction

After 20 minutes the virus is deactivated. It is then put in a machine which isolates the genetic information. This RNA is amplified to ensure any belonging to the coronavirus is detected.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4 Polymerase chain reaction (PCR)

Probes designed to bind to the virus' RNA alert the machine to the presence of the virus' genes.


© Getty

5 Reading results

The machine displays the amount of virus detected in a sample. Scientists record whether the number is above the threshold which determines a positive result. This limits the chance of a false positive result.


© Getty

"There's only one sample for each person, so you have to get it right the first time"

THE SALEM WITCH TRIALS

How mass hysteria and misinformation in 17th-century America became a cautionary horror story

Words by **Ailsa Harvey**

© Joe Cummings

The term 'witch' most likely conjures up a specific image in your mind, one of female figures with suspicious bubbling cauldrons and bulging warts. The term carried the same connotations in the 17th century, a witch being someone who obeyed Satan and had what was thought to be unusual powers. In these dark times, spell-casting and acts of evil were seen everywhere.

Many of us accept that our lives will come with elements of greatness and events of misfortune. When unfortunate things happen, we may feel the need to find a reason, or a cause to blame. But how far would you go to place this blame? Would you make up a story that you knew would get someone killed? This was the reality for victims of the Salem witch trials. They were either in the wrong place at the wrong time, or they didn't fit in with the ideals of their society.

In the 1600s Salem, Massachusetts, abided by Puritan values, which included believing in demons and the devil in everyday life. The large majority of the population followed the Bible rigidly. If anyone was perceived as a threat to this way of life, there was a conveniently simple solution used to banish them: declare them to be a witch. This played on the idea that anything outside what was believed to be the correct way to live must be the work of the devil. Many couldn't understand other ways of living. Rifts between people made it easy for them to accuse each other of witchcraft, even knowing the harsh consequences.

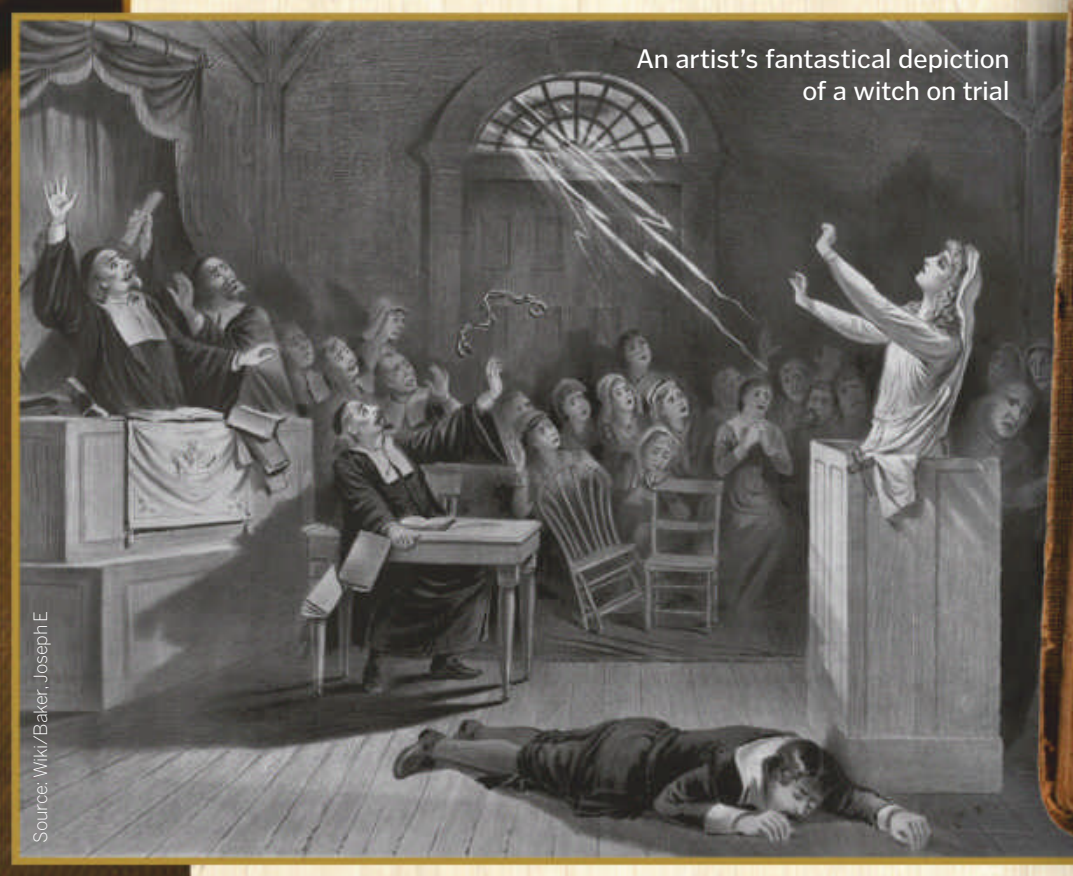
In modern times it might be hard to fathom that so many could truly believe witches existed at all, let alone lived among them. But these beliefs were prevalent across Britain, parts of mainland Europe and America in the 16th and 17th centuries. Witchcraft was regarded as one of the greatest crimes of the time, with courts designed primarily for witches.

When enough people accept something, it becomes the truth. In the case of late 17th-century Salem, the truth was a terrifying one. Imagine believing that the people who live around you could be communicating with Satan and dictating your life. Just like the news today can spread knowledge and concern effectively throughout society, the worrying topic du jour in 1692 was witchcraft.

Herbalists and healers were an obvious scapegoat. As people who understood elements of medical science and worked to help others recover from sickness, at the time people were amazed by their skill. While the response should have been one of gratitude, those who didn't believe these medical miracles were possible needed answers. Unfortunately magic was the only available answer for those who didn't understand, and healers were seen as sorcerers.

"A witch was someone who obeyed Satan"

There was no precise vision of what these witches were. All that was known at the time was that they were dangerous and powerful. The majority of those who were convicted of



An artist's fantastical depiction of a witch on trial

Source: Wiki/Baker, Joseph E

HOW TO SPOT A WITCH IN 1692

Female suspect

Over three-quarters of those on trial were female due to the sexism of the time. Women were considered inferior by Puritans and more likely to be tempted to turn to witchcraft. If someone had many female friends, they were thought to be conspiring with them.

No children

If a woman was unable to have children, they were believed to be cursed. They would be blamed for casting spells on their unborn children and often their neighbours' children too. If a neighbour's child fell ill, the suspected witch was believed to have cursed them out of jealousy.

Spoiled produce

If milk had curdled in someone's house, this was thought to be a sign of witchcraft. Cows were a large part of livelihood in the 1600s, and black magic was often the only explanation for any issues with the cattle.

Talking to self

If you're prone to chatting to yourself, you would have wanted to control this in the 17th century. It was thought to be a sign that someone was possessed.

Left-handed

Being different wasn't always a good thing. Because being right-handed was most common, using the opposite hand was called 'a mark of the devil'.

All images © Getty

© Getty

witchcraft were female. Of the 19 people killed by hanging in Salem, only five were men. Another man was tortured to death with heavy stones as the villagers tried to get him to confess.

Although some were forced to plead guilty, it wasn't necessary; the word of the accuser was often enough. The mere idea that witchcraft could be real often struck such fear into a jury that the accused was convicted, in their minds, before the trial had even begun. But how could such loose evidence be used to determine a person's fate within a courtroom, designed to allow fair decisions to be made? One reason was that different courts were established specifically to test witchcraft, separating these cases from regular crimes. With new rules and procedures fabricated for the new witch courts, the accused individual would be put through a series of tests that lacked evidence and legitimacy. These could vary dramatically between each hearing, but they often tested unrelated skills or were open to being staged purely in order to convict the innocent.

As people in Salem got used to witchery being an answer to any misfortune in their lives, cases spiralled out of control. With no need for real proof of witchcraft, a rising number of people were being convicted, all because the communities needed a scapegoat for their troubles: a recent smallpox epidemic had caused widespread suffering, while tensions and rivalry grew with the neighbouring town. Not knowing when Salem would be under attack, or when a loved one would suffer, witch hunting could have served as a means of regaining power, seeking out the surrounding danger before it found them.

THE YEAR OF HYSTERIA

How did two children cause their city to become bewitched in a matter of months?

Research shows that Tituba, the first Salem witch arrested, was a South American native

Source: Wikimedia Commons

15 January 1692

First afflicted

Young cousins Abigail Williams and Betty Parris began having fits and acting strangely. Recorded by those close to them to claim to see spirits and occasionally scream in pain, their family wanted answers as to what was happening to their children. After visiting a local doctor, their symptoms were described as being the result of witchcraft. This was an easy diagnosis, as it was unlikely to be questioned in great detail. Witchcraft had already been acknowledged for almost a century in the surrounding area.

Passing blame

Under pressure Betty and Abigail accused three women of witchcraft, who were arrested. This was a common pattern: making it someone else's fault was a way to be excused. One of the three women, Tituba, confessed, and went on to tell of many women in Salem who she thought were under the influence of Satan. This system, which saw the number of potential witches growing in number, sparked the rise of the Salem witch trials.

29 February 1692

This burial area is where the Salem witch trials took place. Now it serves as a reminder of the past

© Alamy

Significance

It was in 1702 that the General Court declared the events of 1692 as unlawful. A decade later the families of victims were given money in an attempt to make up for their loss, and in 1957 the state of Massachusetts formally apologised for the past. While the events nearly three centuries ago seem distant from our lives today, it was only in 2001 that the last of the victims was exonerated.

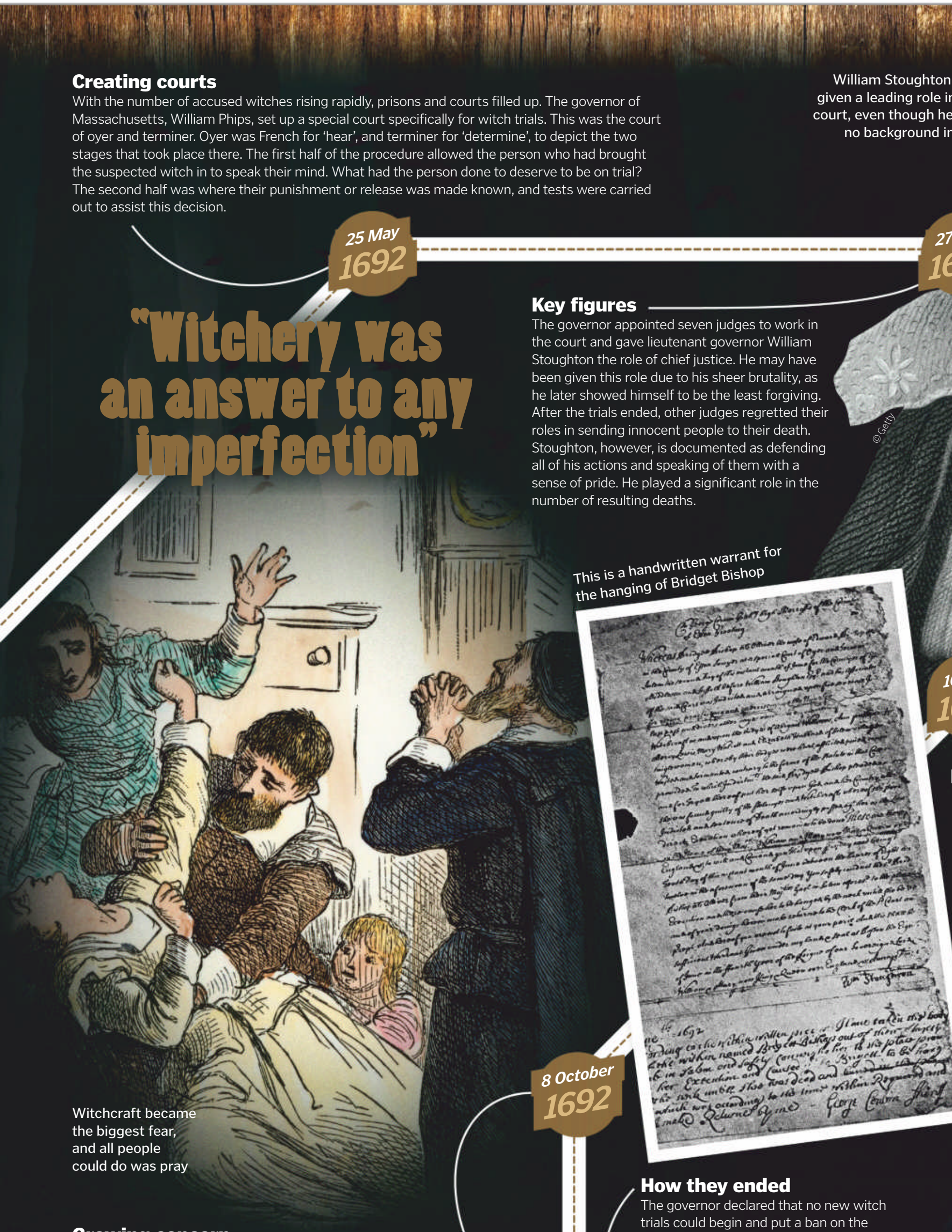
The lessons learned from these trials have also shaped courts of today. Defendants are given a representative to ensure that not everybody is against them, as was the case in many witch trials. Arguably most important, people are presumed innocent until proven guilty. No longer do court proceedings incessantly attempt to force guilt.

1700s-

"Witchery was an answer to any imperfection"

Creating courts

With the number of accused witches rising rapidly, prisons and courts filled up. The governor of Massachusetts, William Phips, set up a special court specifically for witch trials. This was the court of oyer and terminer. Oyer was French for 'hear', and terminer for 'determine', to depict the two stages that took place there. The first half of the procedure allowed the person who had brought the suspected witch in to speak their mind. What had the person done to deserve to be on trial? The second half was where their punishment or release was made known, and tests were carried out to assist this decision.



Witchcraft became the biggest fear, and all people could do was pray

© Alamy

Growing concern

In the space of a few months, 19 people were sentenced to death by hanging, and people were worried about the large number they had observed were clearly innocent. A Boston merchant called Thomas Brattle wrote a letter to an English clergyman detailing the trend of convictions based on no evidence. This letter was received, read and circulated.

25 May 1692

Key figures

The governor appointed seven judges to work in the court and gave lieutenant governor William Stoughton the role of chief justice. He may have been given this role due to his sheer brutality, as he later showed himself to be the least forgiving. After the trials ended, other judges regretted their roles in sending innocent people to their death. Stoughton, however, is documented as defending all of his actions and speaking of them with a sense of pride. He played a significant role in the number of resulting deaths.

William Stoughton was given a leading role in the court, even though he had no background in law

© Getty

27 May 1692

10 June 1692

Hanging begins

The first victim was Bridget Bishop. She had many people come forward to accuse her of witchery due to their distaste at her way of life. In a Puritan society where the majority followed the rules of the Bible strictly, Bishop was a clear target. She didn't wear reserved dresses, she stayed out drinking and was known to fight with her husbands. She couldn't be controlled by the religion followed at the time, and many in the area were concerned that she was a bad example. With witchcraft becoming an easy way to punish without solid evidence, Bishop had many people claim she was a witch. This led to her being the first to be officially executed in the Salem witch trials.

© Getty

This is a handwritten warrant for the hanging of Bridget Bishop

8 October 1692

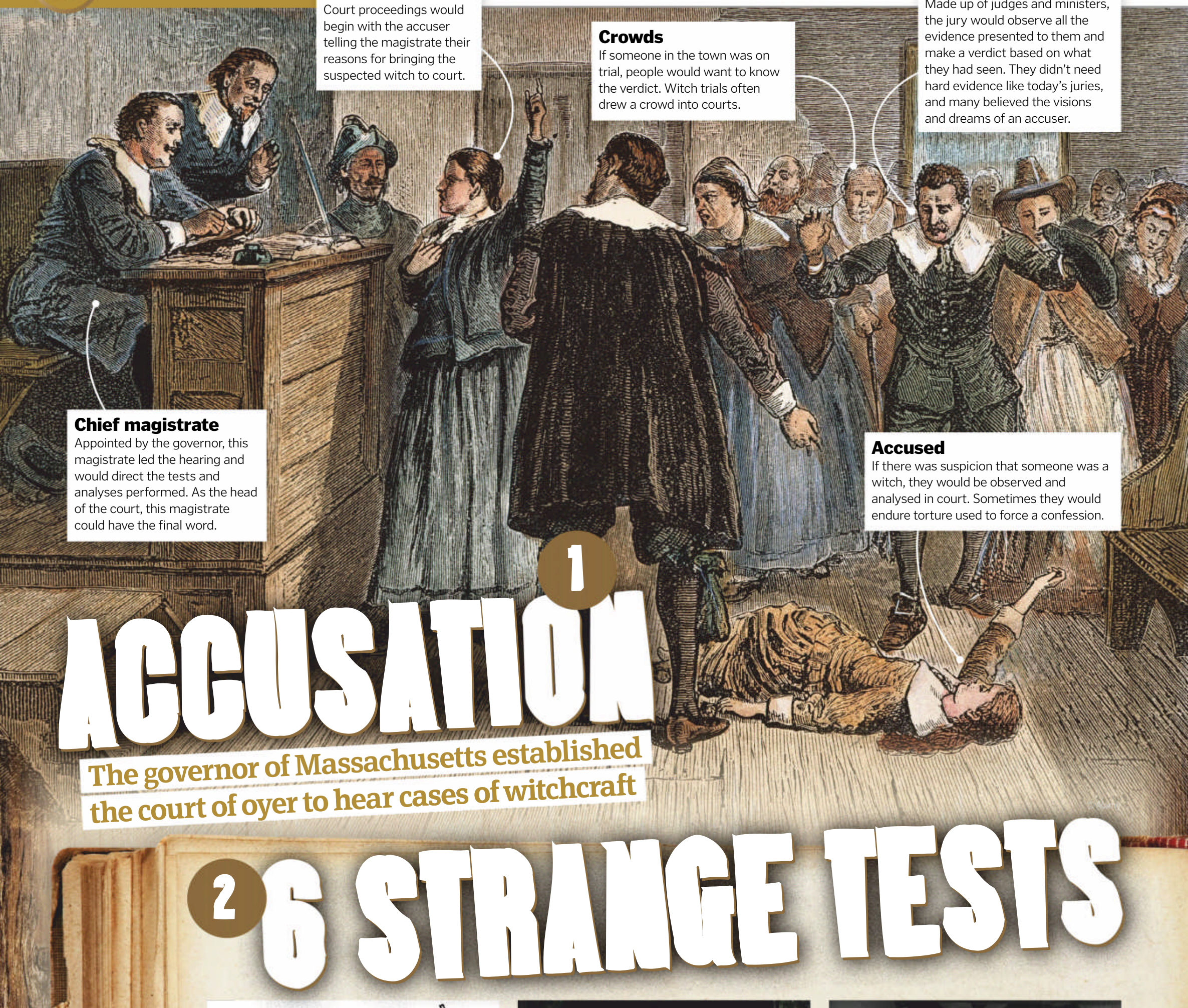
How they ended

The governor declared that no new witch trials could begin and put a ban on the broadcasting of any that were ongoing. Appearing as a hero to those who were suffering with these accusations, the tipping point for Phips was that people were beginning to accuse his own family. When his wife was called a witch he saw the damage closer to home. He banned the trials, expressing that the system got out of hand.

12 October 1692

William Phips received a letter from Queen Mary supporting his decision to end trials

Source: Wiki/Thomas Child



Accuser
Court proceedings would begin with the accuser telling the magistrate their reasons for bringing the suspected witch to court.

Crowds
If someone in the town was on trial, people would want to know the verdict. Witch trials often drew a crowd into courts.

Grand jury
Made up of judges and ministers, the jury would observe all the evidence presented to them and make a verdict based on what they had seen. They didn't need hard evidence like today's juries, and many believed the visions and dreams of an accuser.

Chief magistrate
Appointed by the governor, this magistrate led the hearing and would direct the tests and analyses performed. As the head of the court, this magistrate could have the final word.

Accused
If there was suspicion that someone was a witch, they would be observed and analysed in court. Sometimes they would endure torture used to force a confession.

1 ACCUSATION

The governor of Massachusetts established the court of oyer to hear cases of witchcraft

2 6 STRANGE TESTS

© Alamy

Sink or float
The theory behind this test was that a cursed person would be rejected by the water. Having been stripped of their clothes and thrown into the water, their position in the water would determine their fate. If the accused floated, the water was confirming that the body was riddled with a curse. Those who sank and inevitably drowned were pulled out by a rope and declared innocent.

© Alamy

Bible reading
If public speaking isn't your strong point, you wouldn't have wanted to be accused of witchcraft in the 17th century. During trial, prayers from the bible would need to be recited by the accused. If there were any errors made – even a small slip up when reading a verse – this would be interpreted as the devil showing his presence within the defendant.

© Getty

Magic touch
If the accused witch on trial touched someone, or had some kind of contact with them, and that person's physical condition drastically changed, it could be down to chance or a faked reaction to try and confirm the accusation. The most plausible reasoning in the 1600s was that it was a result of a witch's spell. If an accuser's family member became sick, it could mean death for the accused.

3 CONFESSION OR CONVICTION

Suspected witches were often tortured until they confessed

© Getty

The deadliest day was 22 September 1692, when seven women and a man were convicted and hanged

© Alamy

Why would anyone confess to a sin that held the ultimate price? With harsh penalties put in place to kill anyone who was believed to be a witch, you would think that the best way forward would be to deny the charge at all costs. However, insisting innocence would only make you appear to be a desperate witch.

There was one option that was most likely to save the life of the accused: admitting guilt. If the accused named other people they thought or 'knew' to be witches, then the court might also spare their life.

Bizarrely, those who insisted they weren't witches were often executed, while those who openly confessed were often spared. Some people started to realise that this was their only option if they wanted to live, while others saw lying as such a sin that they couldn't bring themselves to admit to being something they knew they weren't. The belief of being sent to hell for lying was worse to them than death itself.

It was in the court of terminer where a person's guilt would be decided. After the hearing and tests had taken place, chances are the accused would still be insisting that they were innocent. If those deciding had gone into court wishing to find the defendant guilty, then one of the many tests would have given them an excuse to sentence them to death. In Salem, when found guilty the proclaimed witch was hanged. In other places, such as Europe and during earlier times, witches are known to have been burned alive, while some were tortured and stoned to death.

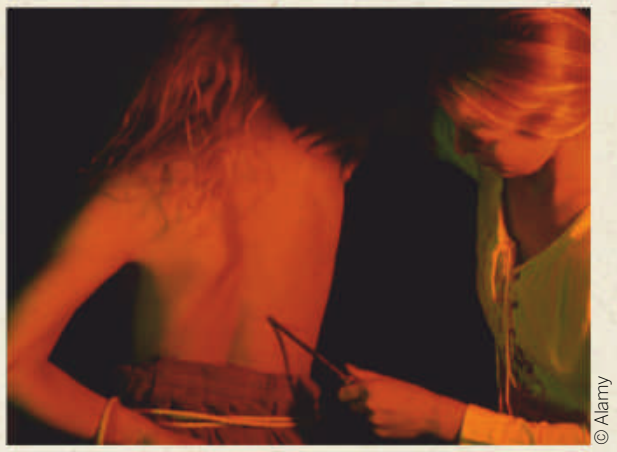
After hanging, the bodies were discarded like rubbish into a ditch near the site. Family members and loved ones who didn't believe the dead to be witches would be heard crying through the night. Some took the discarded bodies to give them a proper burial.

"Insisting innocence would make you appear to be a desperate witch"

© Getty

Witch cakes

Dogs were believed to be witches' companions – thought to be serving the spellcasters as their faithful familiars – and so some tests involved using these animals too. The witch cake was a rye cake made with the urine of the accused. This was then fed to a dog, and the dog was then observed for any signs of bewitchment. This could be any behaviour deemed unusual.



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Suspicious marks

Any mark on the body that stood out as being different could end up being classed as a 'devil's mark'. These included birthmarks, moles, scars and blemishes. This test was a good one to do when the accuser wanted there to be little chance of any innocence being proven. The marks which were classified as being the work of the devil were so broad that almost everyone could be found guilty.

Source: Wiki

Incantations

Sometimes the alleged witch would be ordered to summon the devil with a verbal statement. While this was happening, the crowds would watch someone who was having a fit or was in a trance to see if there were any changes in their condition. Unfortunately for the accused, a reaction to this recitation could be easily faked by a member of the crowd who wanted to see them convicted.

Hoover Dam construction

It was one of the most ambitious projects in the world, but how was the Hoover Dam constructed?

In the early 20th century, the lower region of the Colorado River was considered as a site for flood control and a potential source of hydroelectric power for the growing demands of western US states. What would be known as the Hoover Dam was authorised by President Calvin Coolidge in 1928, and construction began by building conglomerate Six Companies in March 1931. At the time the Hoover Dam was the largest in the world, requiring over 3.3 million cubic metres of concrete to build the structure, including the power station.

Before the dam could be built, foundations had to be laid, and over 1.3 million cubic metres of loose rock and sediment were removed from the bottom of the Colorado River to reach stable bedrock. The foundation was reinforced with a grout curtain, and the canyon walls were similarly stabilised by drilling holes up to 46 metres deep into them and filling cavities with more grout. Chief engineer John L. Savage had decided it would be an arch-gravity dam, which combines the main features of two different types of dam: the arch part is a concave face that leans towards the water, deflecting some of the pressure onto the canyon walls, while the gravity part of the design is the enormous weight of the dam that thickens considerably from the top, where it is 13.7 metres thick, to the bottom, which is 201 metres thick. This helps to resist the immense force that the Colorado River can generate with its 5.5 million-tonne weight.

To help with dissipating the heat generated by all this concrete setting, approximately 950 kilometres of steel piping delivered water cooled by the dam's dedicated ammonia refrigeration plant through the 230 concrete blocks that make up the structure. Without this active cooling system in place, all of that concrete would still be setting today!

© ThinkStock

Diverting the Colorado River

Constructing the Hoover Dam would have been impossible with the Colorado River still flowing through Black Canyon, so the builders endeavoured to divert the course of the river. Four tunnels with a combined length of over five kilometres were dug into the canyon walls and around the dam site. The river was diverted into these tunnels by blocking its natural course with rubble, as well as detonating a hole in a cofferdam – a temporary enclosure that stopped the river draining into the diversion tunnels.

This was only performed for the two tunnels on the Arizona side of the canyon. The two drainage tunnels on the Nevada side were held in reserve for the higher waters in spring and summer.

Hoover Dam structure

How It Works explores one of the world's greatest engineering feats

Lake Mead
At maximum capacity the lake on the upstream side of the dam can yield 219,700 kilograms per square metre of force at its base.

Highway
For many years the top of the Hoover Dam served as a public highway between Nevada and Arizona – until the Hoover Dam Bypass was opened in 2010.

Spillway inlet
Overflow from Lake Mead drains downstream via these inlets. They've been used just twice since the dam was built.

Intake towers
Water drains into these towers to supply the power station.

"The Hoover Dam was the largest in the world, requiring over 3.3 million cubic metres of concrete to build"

Elevator
An elevator takes tourists down a 152-metre shaft to the base of the dam to the power plant.

Penstocks
The pipes that deliver water to the power plant are known as penstocks. The water in these pipes is under high pressure from the lake behind the dam.

The statistics

Hoover Dam

Height: 221 metres

Crest: 379 metres

Weight: 6.6 million tonnes

Max upstream depth: 180 metres

Max water pressure: 219,700 kilograms per square metre

Total material excavated: 4.2 million cubic metres

Average annual power: 4 billion kWh

Generating power

The Hoover Dam's hydroelectric power plant is located on the downstream side at the bottom of the dam. Excavating the area for the station was finished in 1933, after excavations for the dam itself. Concrete began to be poured for the plant at the end of the same year, and continued for the next two years, even overlapping with the filling of Lake Mead behind the dam in 1935. With war brewing in Europe and the vulnerability of the plant considered, 1.1 metres of concrete, rock and steel topped with tar formed a robust ceiling. Three Francis turbine-generators were installed in 1937 when the power plant went online, with 14 more added over the decades. Its average power generation in nearly 90 years has been around four terawatt hours, helping to fulfil the huge power requirements of Las Vegas, among other West Coast communities.

Power house
Originally rated at a 1.344GW capacity, the dam's current installed power capacity is 2.078GW.

© Thinkstock

KEY DATES
HOOVER DAM

1928 A dam in Black Canyon is authorised by Congress, and Six Companies wins the contract.

1935 President Roosevelt formally opens the dam on 30 September to a crowd of 10,000.

1947 The 'Boulder Dam' name is removed and the House of Congress bestows the name 'Hoover Dam' instead.

1961 The last of the 17 turbines is installed into the power station, bringing it up to full capacity.

1983 The 1983 floods see the Hoover Dam use its spillways for only the second time – the first being a 1941 test.

DID YOU KNOW? The Hoover Dam was initially called Boulder Dam, as Boulder Canyon was the original site location

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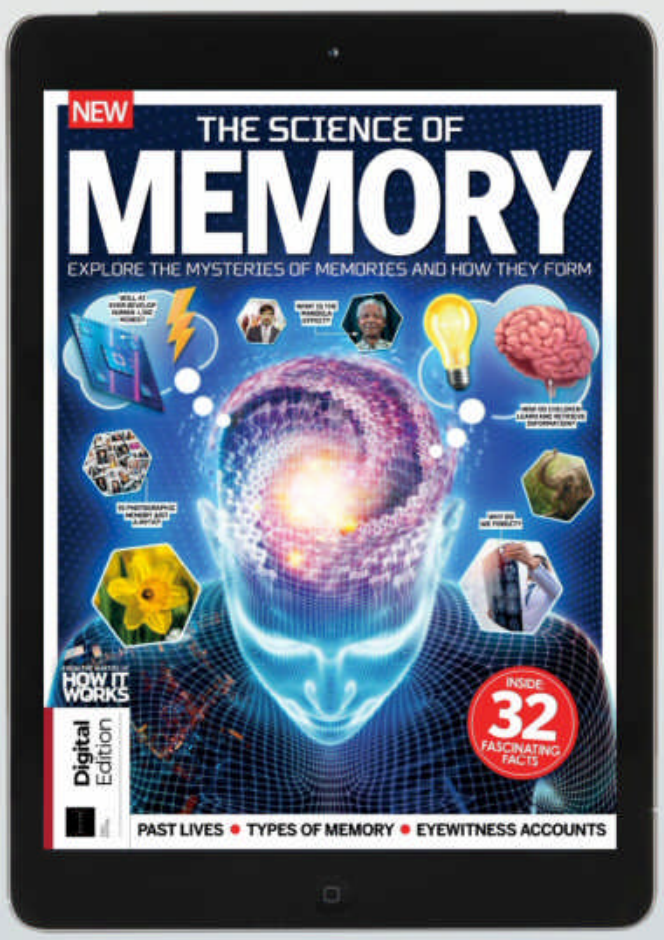
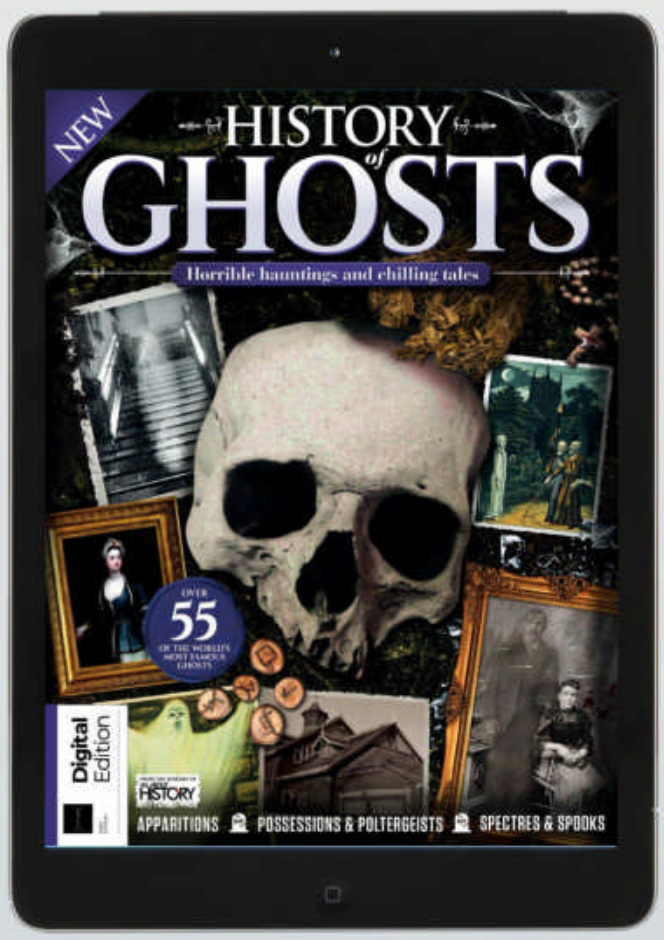


The Science of Memory

From our earliest recollections of childhood to what we did last night, our memories make us who we are, enabling us to chart our life to date, recall pivotal moments and plan for the future. Yet how much do we actually know about memories? How and why do they form? How many types of memory are there? Why do we have 'false' memories? Is it possible for memories to be passed from one generation to the next? In this book you'll discover the answers to all of these questions and many more.



History of Ghosts

This book is packed with spooks, spectres and horrible hauntings. Discover the history of ghosts and their believers from the ancient world to the present day. Find out why people believe in ghosts and possible scientific explanations behind haunted houses, spectral lights, scary sounds and spooky apparitions. Explore hoaxes and horrors from some of the world's most eerie locations, and delve into stories of the phantoms, wraiths and spirits that are thought to frequent them.

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VAMPIRE PLANTS

Words by **Scott Dutfield**

Discover the botanical parasites draining the life from their leafy hosts

© Getty

Yellow rattle (*Rhinanthus minor*) has a particular taste for grasses and can suppress their growth by as much as 60 per cent

© Getty

They don't shy away from sunlight, nor cower from the scent of garlic. However, these botanical vampires share an equal thirst for the 'blood' of other organisms. Long before Count Dracula was terrorising the people of Transylvania, parasitic plants have been draining the life of others. There are over 4,500 plant species that parasitise plants around the world, but some are more obvious than others. For example, the blood-red corpse flower *Rafflesia arnoldii* is rare to find, but easily spotted thanks to its almost cartoonish appearance. However, like a vampire stalking the shadows, many parasitic plants carry out their vampiric behaviour in the dark depths of the soil.

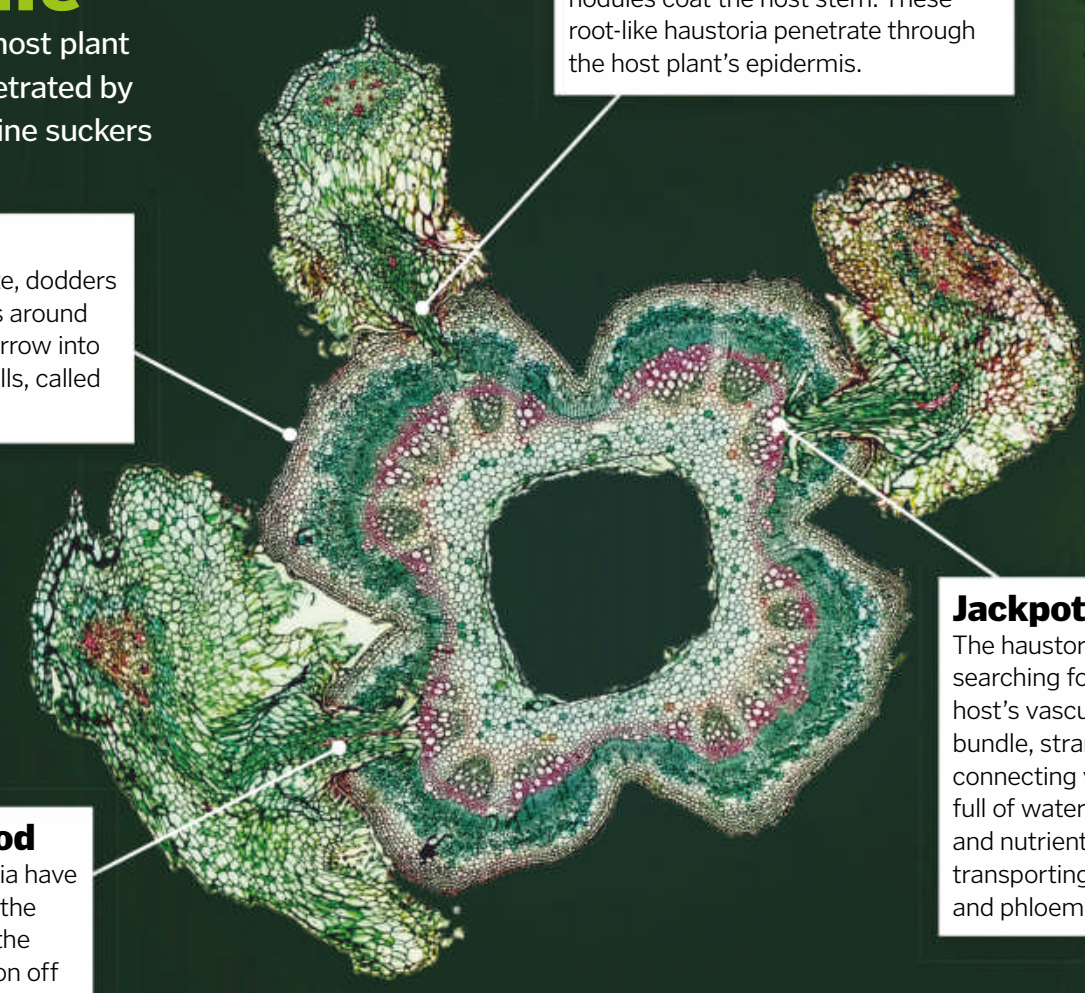
As with any parasitic organism, these leafy demons benefit from stealing vital resources. Just as the blood flowing through our veins delivers vital oxygen to our organs via blood vessels, the 'blood' of a plant is the water, soluble sugars and nutrients that travel through a network of vessels called xylem and phloem. It's these vessels that the parasitic plants seek out. Vampiric plants have evolved into two groups: the first is a group called holoparasites. These plants lack the ability to produce green leaves filled with a pigment called chlorophyll, which converts sunlight into food through the process of

> "There are over 4,500 plant species that parasitise plants"

Draining their life

The stem of a host plant (centre) is penetrated by three dodder vine suckers

© Alamy



Host
As a stem parasite, dodders extend wiry vines around their host that burrow into the host's cell walls, called the epidermis.

Digging for treasure
Along the dodder vines, sucker-like nodules coat the host stem. These root-like haustoria penetrate through the host plant's epidermis.

Jackpot
The haustoria are searching for the host's vascular bundle, strands of connecting vessels full of water and nutrient-transporting xylem and phloem.

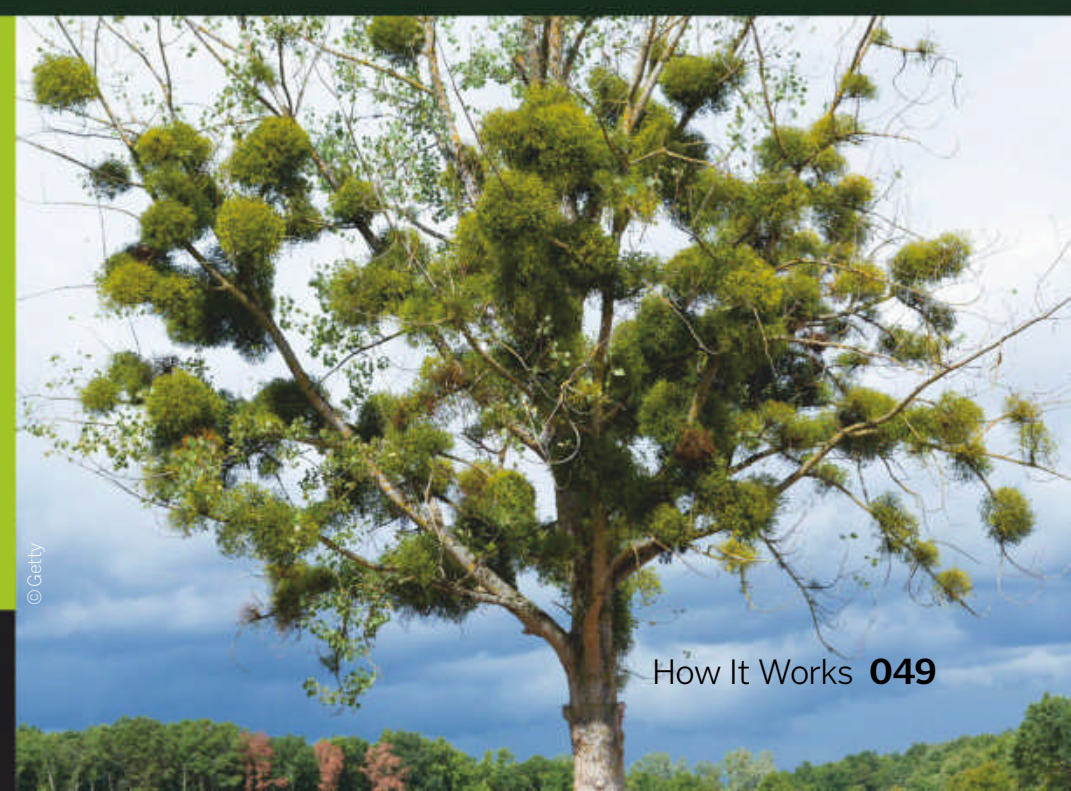
Stealing food
Once the haustoria have gained access to the vascular bundle, the dodder can syphon off water and nutrients.

It takes mistletoe 10 to 15 years to reach 90 centimetres tall

Nightmare before Christmas

Mistletoe has become a symbol of Christmas romance, with those standing beneath it sharing a kiss for good luck. However, its festive featuring is a far cry from its vampiric nature out in the wild. Before it's bundled up in ribbon and hung underneath a doorway, mistletoe spends its life parasitising trees.

It's believed that one of the reasons mistletoe has become a festive favourite is because it remains green throughout winter. While most other plants have lost their verdant glow, mistletoe manages to remain lush due to the vigour of its parasitism. However, if its appetite gets the better of the mistletoe and it grows greater than the host tree can support, both host and parasite will perish in the process. There is one upside to mistletoe, however: studies have shown that bird population numbers suffer when mistletoe is removed when compared to areas where it remains. Birds likely use mistletoe berries and flowers as a food source.



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HOW HELLROOT GROWS

Otherwise known as *Orobanche minor*, this vampire plant starts draining its victim as a seedling

Orobanche minor
Hellroot can be found across south and west Europe to northern Africa and western Asia. This plant is an obligate parasite and depends completely on its host for survival.

Host
These parasitic plants have a particular taste for families of plants called Fabaceae and Apiaceae, which include species of peas, beans, celery and parsley.

Parasitism
Over several weeks – or even months – the parasite will swell and form nodes around the root called tubercles, leaching nutrients before emerging as flowering shoots above ground.

Seedlings
A single hellroot plant can produce more than 500,000 seeds, which can remain viable for germination for decades beneath the soil.

Stimulation
Seedlings begin to germinate when they detect the production of a chemical in the soil called strigolactones, produced by a potential host plant.

First bite
Having sniffed out their new host, hellroot seeds attach to the root of the host via their haustoria.

"These leafy demons benefit from stealing vital resources"

© Illustration by Nicho as Forder

Hellroot is native to Europe and North Africa and typically reaches a height of 50 centimetres

© A.amy

The vines of a dodder plant are lined with little suckers for the parasite's haustoria to pierce through the host's cells

© Getty

photosynthesis. They therefore need to obtain all of their nutrients by sucking it out of a host plant.

The second group are called hemiparasites. Hemiparasites' thirst for food is not always limited to what they can pillage from other plants. The plant doesn't rely solely on its host for survival, and can grow leaves for photosynthesis while also using modified roots to burrow into the roots of other plants to steal their internal water.

But how do both of these types of vampire plant suck the life from their neighbours? Lacking the infamous fangs of the undead, they use a root-like tissue called haustoria that creeps over to either the roots or stem of the host and penetrates its cell wall, in some cases with the assistance of enzymes that break down the wall. For species such as the dodder plant, the haustoria appear similar to the suction cups on an octopus tentacle. Once inside the host the haustoria seek out the host's network of xylem, a collection of cells that transport water around the plant, or phloem, which deliver organic compounds such as sugar sucrose. Now the parasitic plants can begin to feast, sucking the available water and nutrients through a haustoria straw.

Although these plants rely on their hosts to draw sustenance, they retain the ability to produce colourful flowers for pollination and grow seeds. Although different species vary in their methods of seed dispersal, the common theme is that they must find their way to neighbouring plants, which will become the new hosts for the seeds. During germination seedlings will find and attach to the roots of other plants and begin their growth through the soil, siphoning nutrients as they go.

With all parasites, plant or animal, there are some negative consequences for the host. Although some host plants can continue growing and remain relatively unchanged by the presence of a parasite, for others it's a death sentence. Dodder plants in particular can wreak havoc on crop plants, literally sucking the life out of them before moving on to their next victim.

5 FACTS ABOUT PERILOUS PARASITES

© Getty

1 *Rafflesia arnoldii*
The largest known flower in the world is a rare parasitic plant almost one metre across that can be found in southeast Asia. Its crimson buds emerge from the bark of its host plant, with the rest of the body remaining hidden inside the host.

© Getty

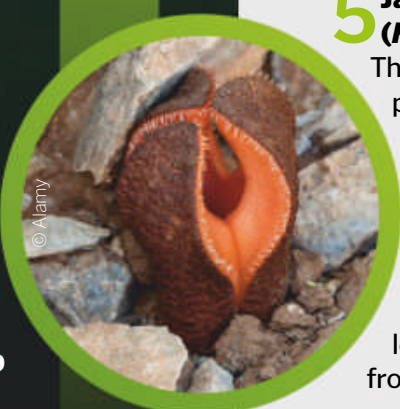
2 Indian pipe (*Monotropa uniflora*)
Unlike other parasitic plants, this ghostly plant uses a fungus as a middleman to gain nutrition. The fungus feeds nearby conifers, and the Indian pipe takes the sugars obtained from the trees from the fungus.

© Getty

3 Western Australian Christmas tree (*Nuytsia floribunda*)
This parasitic tree can grow up to ten metres tall and is believed to be able to hijack the roots of plants up to 150 metres away and gain nutrients for growth. During summer it erupts with bundles of golden flowers.

© Getty

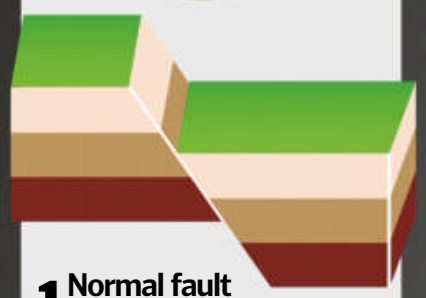
4 Bird's-nest orchid (*Neottia nidus-avis*)
Found around the base of trees throughout the UK, this sickly looking holoparasite feasts on tree roots. It gets its name from its tangled root system, which looks like a messy bird's nest.



© Alamy

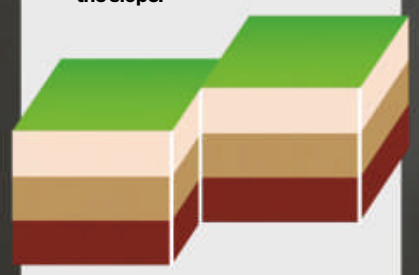
5 Jackal food (*Hydnora africana*)
This extremely rare parasite emits a fragrance of rotting meat to attract dung beetles for pollination in regions of southern Africa. Often mistaken for a fungus, it has no leaves and gains food from the roots of trees.

TYPES OF FAULTS

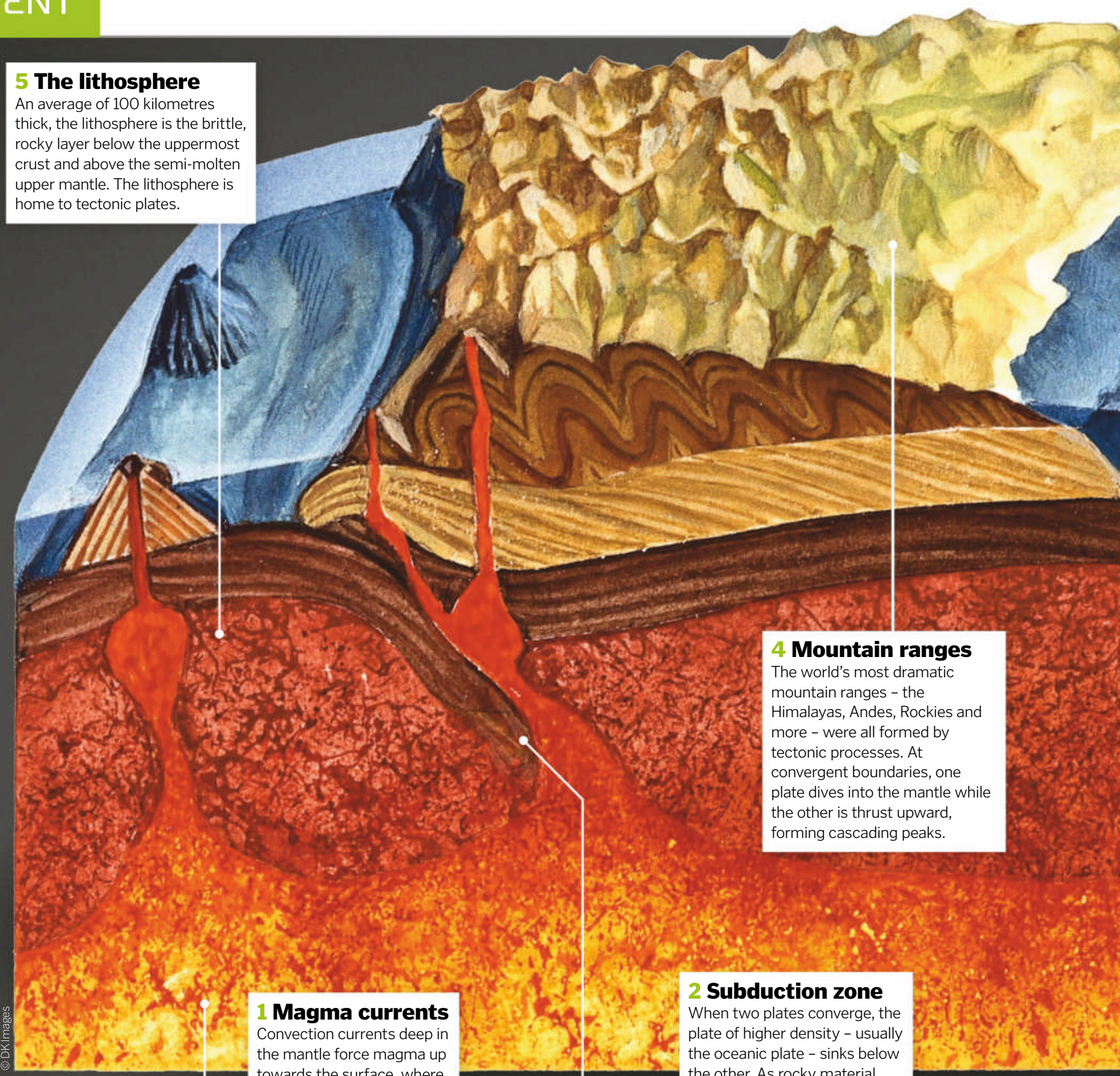


1 Normal fault
Caused by stretching the lithosphere, the hanging wall drops down in the direction of the slope of the fault.

2 Reverse fault
Caused by compression, the hanging wall is pushed up against the direction of the slope.



3 Strike-slip fault
Lateral scraping movement without any dips or slopes.



5 The lithosphere
An average of 100 kilometres thick, the lithosphere is the brittle, rocky layer below the uppermost crust and above the semi-molten upper mantle. The lithosphere is home to tectonic plates.

4 Mountain ranges
The world's most dramatic mountain ranges – the Himalayas, Andes, Rockies and more – were all formed by tectonic processes. At convergent boundaries, one plate dives into the mantle while the other is thrust upward, forming cascading peaks.

1 Magma currents
Convection currents deep in the mantle force magma up towards the surface, where it either pierces the crust as lava or directs the motion of the tectonic plates.

2 Subduction zone
When two plates converge, the plate of higher density – usually the oceanic plate – sinks below the other. As rocky material fragments and melts in the mantle, it releases seismic waves and triggers volcanoes.

© DK Images

An earthquake can render a town unrecognisable

Earthquakes

Earthquakes are not-so-subtle reminders that the Earth is very much alive – and kicking

Our planet isn't the solid hunk of rock it appears to be. It is a shifting, boiling, sliding, sinking, churning ball of superheated magma with a thin, brittle skin. This skin, called the lithosphere, is fractured into 15 large and small segments called tectonic plates. The deep, molten seas of Earth's mantle are home to giant convection currents that push magma upward and outward.

The tectonic plates float atop these vast subterranean currents, bumping and grinding against each other as they jostle for position. As they move around they forge cascading mountain ranges, deep oceanic gorges and strings of volcanic islands.

Imagine two colossal hunks of rock – some the size of whole continents – trying to scrape past each other, or indeed over each other. The jagged edges of the plates periodically get jammed together, storing up tremendous potential energy along cracks called fault lines. When the rock finally gives way, the plates slip and

3 Divergent boundary
In divergent boundaries like the Mid-Atlantic Ridge, a long seam of underwater volcanoes creates new lithosphere. The new plates grow perpendicular to the ridge in opposite directions.

Tectonic plates explained

Understanding how earthquakes happen

The Earth's tectonic plates

Afloat on a sea of magma

Divergent boundaries

These are long seams of volcanoes – usually deep under the ocean – where the Earth's crust is formed. Plates grow away from each other at a rate of 2.5 centimetres per year.

Subduction zones

When two plates converge, one slowly plunges under the other, swallowing up the Earth's crust. Subduction zones are the world's most active earthquake and volcano hotspots.

Plate movement

Convection currents from the Earth's molten core rise towards the surface and spread outward. The brittle lithosphere rides this subterranean sea of magma like a conveyor belt.

PLATE KEY
Earth's plate layout
- Subduction zones
- Divergent boundaries
- Plate movement

dip violently along the fault, releasing megatonnes of stored energy as seismic waves.

Originating at the focus of the fracture – tens or even hundreds of kilometres below the surface – seismic waves ripple outward in all directions. High-frequency body waves travel quickly through liquid and rock, but do little damage. It's the lower frequency surface waves – which twist, roll and tear the crust like paper – that end up causing the most devastation.

Using ultra-sensitive seismographs, geologists estimate there are 500,000 earthquakes every year, although only about 100 of these do enough damage to make headlines. But when the big ones strike, they are the world's deadliest geological phenomena.

Undersea earthquakes can trigger killer tsunamis that travel across the ocean faster than a high-speed jet. They cause massive avalanches and landslides, and in some areas loose, waterlogged soils can become 'liquefied', causing homes and high-rises to sink into their foundations. In poorer developing countries, even moderate quakes are often enough to topple poorly constructed buildings including schools, churches and hospitals.

Head to head

THE BIGGEST AND BADDEST EARTHQUAKES OF ALL TIME

LONGEST

The Sumatra-Andaman quake

When: 2004
Facts: The quake that triggered the catastrophic Indian Ocean tsunamis of 2004 lasted between eight and ten minutes – an eternity for an earthquake.

MOST POWERFUL

Valdivia quake

When: 1960
Facts: A 9.5-magnitude quake off the coast of southern Chile wrought death and destruction as far away as the Philippines, Hawaii and Japan.

DEADLIEST

Shaanxi quake

When: 1556
Facts: An 8.3-magnitude quake in Shaanxi, China, ripped open 20-metre crevasses, triggered landslides and levelled homes for 300 miles, killing an estimated 830,000 people. It also damaged the Small Wild Goose Pagoda, built between 707 and 709.

MONSTER TRUCKS

WHAT POWERS MASSIVE TRUCKS THAT CAN DRIVE OVER ALMOST ANYTHING?

The phenomenon of monster trucking is a relatively new one. American 4x4 enthusiast Bob Chandler is credited with creating the first monster truck in 1974 when he raised the suspension on his Ford F-250 pickup truck and fitted it with immense 122-centimetre tyres. He then attempted to traverse over two scrap cars in the vehicle, and was surprised at just how easily the truck accomplished the task. A legend was duly born.

Bigfoot 1, as it became known, was in fact a stock pickup truck, with a beefier frame and engine later added to complement the changes in ride height and wheel size. Weighing in at a monumental 5,000 kilograms, Bigfoot 1 wowed the crowds with its original stunts of driving straight over and squashing conventional cars.

Despite these early revelations of newfound motoring entertainment, vast improvements in the build were needed to prolong the life of a monster truck. This soon led to a new, more durable design being implemented.

By the mid-1980s monster trucks used stronger axle housings with 'planetary gears' in the hubs to help turn the wheels and reduce stresses and axle-shaft breakage. Planetary gears work by a main gear in the middle – called a sun – engaging with three surrounding gears – called planets – at the same time. Once engaged the planets rotate around the sun, running along the inside of a ring and giving a three-to-one gear reduction ratio.

These vehicles, now called 'stage-two' trucks, also received heavier frames and axles taken from larger vehicles – but the chassis couldn't handle the extra weight. What's more, a stage-two truck now weighed around 6,800 kilograms. They also operated the antiquated leaf springs as found on early cars, or spring packs that still offered a notoriously harsh ride with little travel in suspension. Inevitably during the early stages of racing competition, drivers often got hurt.

The third and latest evolution of monster truck design has been the most significant. This upgraded iteration cuts costs while improving performance, repair times and driver safety. Introduced in the early 1990s, the main development was in suspension. As a result, current monster trucks now use a series of nitrogen-charged shock absorbers, which compress under load and then expand substantially. Current shocks have around a metre of travel, cushioning the driver on impact

Born from an idea in 1974, monster trucks have since taken motorsport by storm

"The chassis and frame are mounted high above the wheels, making it easier to traverse over large objects"

with the ground from a big jump. Indeed, shocks can now handle the impact of landing a jump from up to 60 metres.

Modern monster trucks also use flotation tyres, usually intended for agricultural use. The tyres need to flex as part of the suspension, making low-pressure agricultural tyres ideal. Due to the volume of air that goes into a flotation tyre, monster trucks only need about ten pounds per square inch (psi) of pressure per tyre.

As these trucks are seen as the brainchild of mid-western American petrolheads, it's only fitting that monster trucks are powered by another of America's greatest traditions: the V8 engine. Big Ford, Chrysler or General Motors engines are most commonly found in competitive monster trucks. Excessively tuned using superchargers and running on methanol, these engines can put down horsepower figures that hit quadruple digits. They can also catapult the five-tonne vehicles to 60 miles per hour in under five seconds. Such rapid acceleration also helps the trucks make large jumps from relatively small ramps, throwing the front of the truck into the air when needed.

Despite such immense power, you're unlikely to find a manual gearbox anywhere near a meaty stage-three monster truck, with the vehicle instead running automatic transmission. Because the driver must contend with steering the truck while operating the accelerator and brake pedals, the presence of a third pedal in the clutch would prove an unwanted distraction. Many monster trucks today use two-speed transmissions, and besides, some automatic transmissions can allow drivers to shift up or

Monster trucks by the numbers

2,000bhp
Horsepower produced by a monster truck engine

10psi
The average tyre pressure for a monster truck

72.42m
The longest ramp jump by a monster truck, recorded in 2013 by Bad Habit

91cm
The amount of 'wheel travel' nitrogen shock absorbers allow stage-three monster trucks

$250,000
The annual cost of running and maintaining a monster truck

168cm
The average tyre height of one of these trucks

5
The average Monster Jam truck team burns their way through several gearboxes a year

9,423cm³
The average size of the displacement of a monster truck's engine

25
scrap cars are crushed by Monster Jam trucks in a typical show

© Getty Images, Corbis

down without the need for a pedal – less for the driver to have to pay attention to.

On the inside, a stage-three monster truck now employs a complex tubular design made from steel and chromium-molybdenum for its frame and chassis, which strengthens the vehicle and protects the driver. This is where the conventional pickup truck ends its association with monster trucks. Instead of using an 'original equipment manufacturer' body, each frame and chassis is custom built. The chassis and frame are mounted high above the wheels, giving massive ground clearance and making it easier to traverse over large objects such as cars and allowing for long travel from the suspension when landing a jump.

> "Any lights, grilles and doors are merely decorative, saving further weight"

A lightweight and durable fibreglass shell covers the frame and engine. Any lights, grilles and doors are merely decorative, saving further weight and ensuring the bodywork is easier to respray after repairs. Moving ever further from their ancestral pickups, some monster trucks are modelled on non-vehicular objects, such as Monster Mutt, or Batman, styled according to the famous superhero. With no conventional doors to climb in and out of the truck, the driver instead enters and exits via an escape hatch in the middle of the cockpit floor.

Monster trucks have traditionally followed a layout akin to that of a conventional American road vehicle, with a front-mounted engine and a driving position to the left of the cabin. However, some of the more modern monster trucks now operate with the driver sitting in the middle of the cabin, with a mid-mounted engine roaring loudly underneath. With more weight now in the centre, monster trucks enjoy greater balance, making them more nimble when performing stunts.

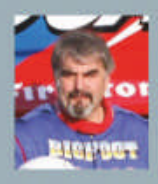
Front- and rear-wheel steering on today's trucks allows them to corner faster and gives the driver a few more valuable seconds to make a turn after coming down from a big jump.

A monster truck built for competition can take three months to a year to build. This depends on the intricacy of the tubular frame and the overall truck's design. Once fully built a monster truck can dominate and even decimate a terrain littered with human-made objects thanks to its excessive weight and power. They may be loud, lairy and disproportionately scaled, but make no mistake: a monster truck is absolutely an engineering marvel.

As such, motorsport involving monster trucks is very popular. Many of America's top-end monster trucks take part in the world-famous Monster Jam, a globetrotting series in which experienced drivers perform sprint races and freestyle events to tens of thousands of spectators. A sprint race is a dash to the finish line between two trucks at a time, where the winner goes through to the next round until just one truck remains. The freestyle event, meanwhile, gives trucks around 90 seconds on the arena floor to dazzle three judges. Stunts typically include jumping up onto and then crushing cars, as well as performing sky wheelies and multiple doughnuts.

Capable of 0 to 60mph in under five seconds, these trucks are mean machines

© Corbis



Taming monsters

Former president of the Monster Truck Racing Association of Europe, Nigel Morris talks about driving a Bigfoot

What's the personal appeal behind monster trucks for you?
My dad put me on a motorbike at the age of six, and I raced for years and did well. I then started racing jet skis, and after one or two other sports I found my way to monster trucks – it's more fun than anything I've done. It's a vehicle that measures 3.7 x 3.7 x 6.0 metres, weighs five tonnes and does 0 to 62 miles per hour in under five seconds. What's not to like?

How did you get into monster trucking?
I was an ex-computer salesman who took a redundancy many years ago and set up a business building custom 4x4s for street use. Then sitting around the campfire late one night at a truck show, a good friend reckoned I could build a better monster truck than the one in action earlier that day. I told my friends we'd start next Saturday. Sure enough, four of my friends turned up at my workshop that Saturday morning, ready to work. We built my first truck, Monstrous, and things started to get more serious. I got in contact with the MTRA in the US and set up the European version of MTRA.

How did Bigfoot 17 come about?
Liaising with the US put me in contact with Bigfoot owner Bob Chandler, who told me he wanted a truck based permanently in Europe. Bigfoot 17 was then built in Daventry, UK, and is largely identical to Bigfoots 9 to 15, with several updates over the years.

How does the monster truck industry in Europe compare to the US?
The industry in Europe is ten years behind the US, mainly due to the arenas. In the US, the Monster Jam arena is on par with Wembley. We've performed on hockey pitch-sized arenas here. We therefore have to tailor what we do to fit the arena, so it's all about the environment.

What repairs or maintenance is needed?
It depends from show to show. These are expensive trucks, so while sometimes you only have to replenish oil filters and fuel, you may need an engine rebuilt, which is approximately £15,000 ($22,800). I've known teams to go through five gearboxes a year.

What must the driver think about when performing a freestyle run?
It's all about control and reaction, and control is down to instinct. A monster truck is no different to operate than a car, other than the rear-axle steering that's controlled by your right hand. A driver thinks, 'What can I hit next that'll be dramatic?' and so you plan a rough route. A truck can do the same jump three times, but get a different landing each time. It's from there when a driver decides if he's going left or right.

Bigfoot: the original monster

Bigfoot is the first and most famous monster truck. Chandler's original was retired in the mid-1980s, but he has continued to name each of his many trucks since in numerical order – the latest is Bigfoot 21

V8 engine
Textbook American muscle engines are favoured for their large capacity and ability to handle extreme power and stress.

Transmission
Two-speed transmissions are mounted high for maximum ground clearance.

Frame
The frame is tubular-welded for rigidity, helping the truck to handle and control better. This also protects the driver in case the vehicle is rolled.

Fibreglass shell
Monster trucks use a fibreglass shell as it's extremely lightweight and simple to repair.

Flotation tyres
Taken from agricultural machines, these make climbing objects easy and allow a cushioned landing afterwards.

Long-travel shocks
These nitrogen-charged shock absorbers have up to one metre of travel to ensure a cushioned landing from big jumps.

Link bars
The four main bars that link the front and rear axles to the frame. They can be adjusted to control how much traction the truck can get.

"A monster truck is absolutely an engineering marvel"

Size matters

	Monster truck	Family saloon	London bus	Smart car	Motorbike
Length	6.0m	4.8m	10.9m	2.6m	2.0m
Width	3.6m	1.9m	2.6m	1.6m	0.7m
Height	3.6m	1.5m	4.4m	1.5m	1.1m
Weight	4,500kg	2,210kg	8,119kg	820kg	170kg

Hovercraft

How do these incredible machines traverse both land and sea?

The ability of hovercraft to cross dry land as well as water has seen them employed in the military and tourism sectors for many years. Although once billed as the next generation of transportation, they have somewhat decreased in popularity over the last decade. Despite this, their usefulness is still readily apparent.

The core principle of a hovercraft is that the hull of the vehicle is suspended on top of a giant cushion of air, held in place by flexible rubber that allows it to traverse difficult terrain or choppy waves without being torn apart. At the centre of a hovercraft is a huge fan that fires air downwards, pushing the hull off the ground as high as two metres. Smaller fans on top of the hull push air backwards, giving the hovercraft forward momentum. Rudders direct this flow of horizontal air to allow a hovercraft to change its direction.

Traditional hovercraft have an entirely rubber base that allows for travel on land or sea, but others have rigid sides that, while suited only to water, can have propellers or water-jet engines attached for a quieter craft.

Hovercraft have been in use for over 50 years

© Andrew Berridge

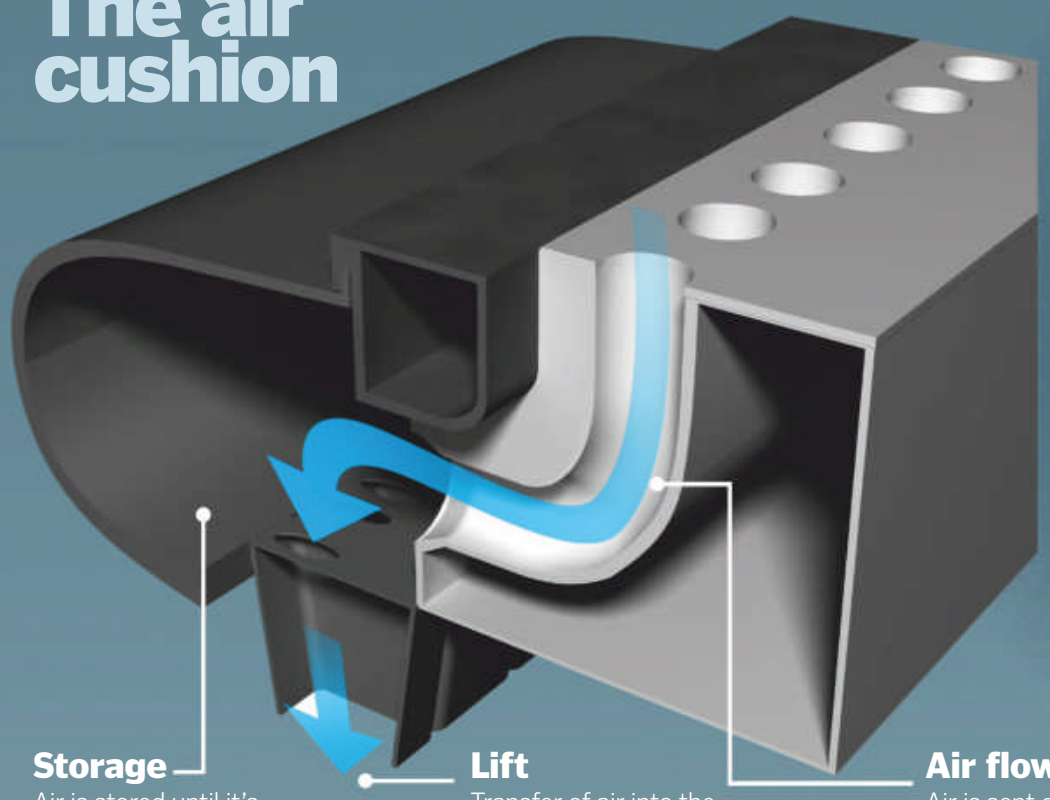
© Alex Pang

Cargo
Most modern hovercraft are used for military purposes, like this Landing Craft Air Cushion (LCAC), which can transport vehicles and troops with ease.

Skirt
This flexible and inflatable barrier traps the cushion of pressurised air beneath the hull in addition to increasing the height of the hull to allow it to move over obstacles.

Plenum chamber
The region of trapped air underneath the craft is known as the 'plenum chamber', which controls the escape of air to create a high-pressure environment and thus a circulation of controllable air.

The air cushion



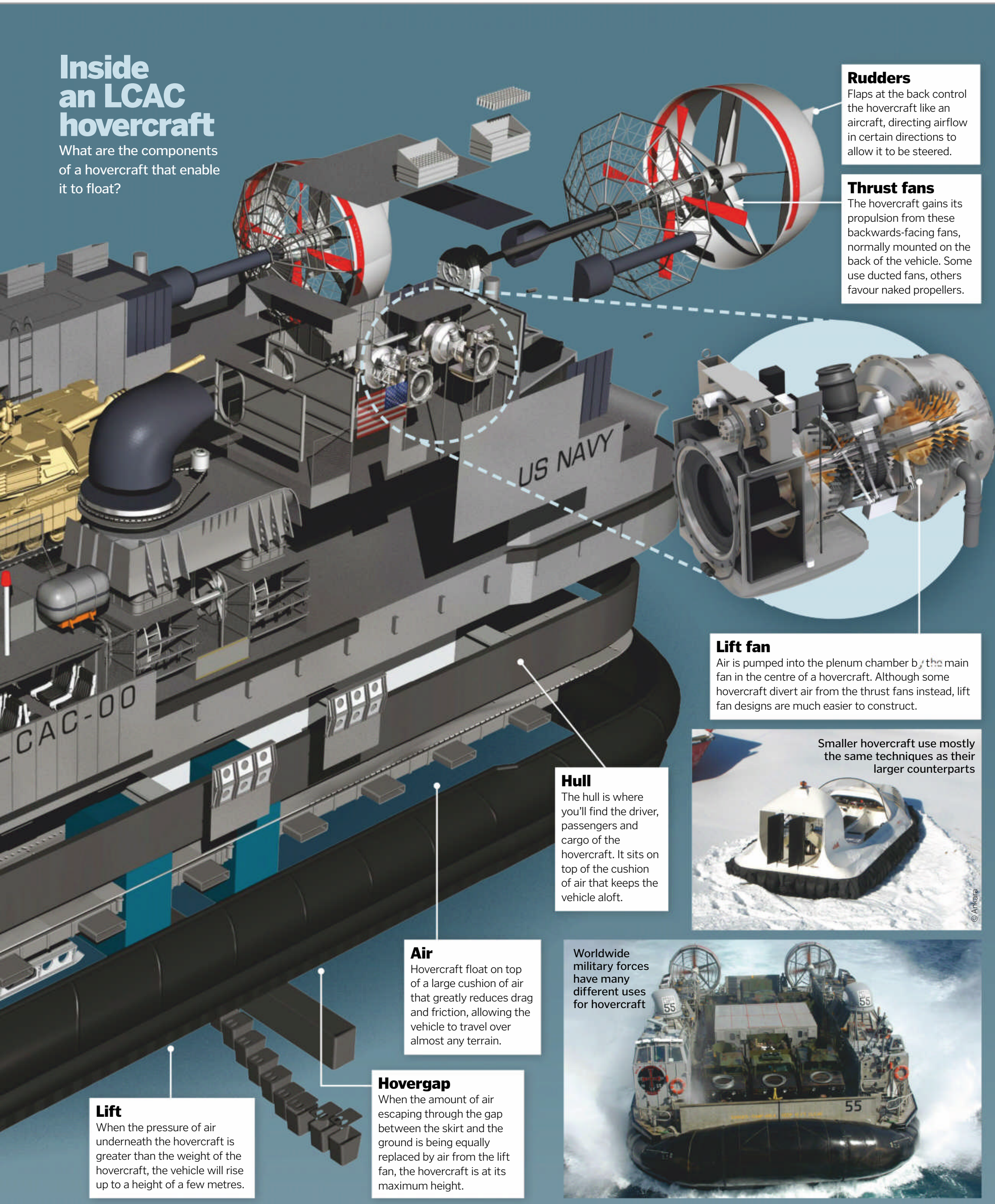
Storage
Air is stored until it's needed to give more lift, when air escapes through the hovergap.

Lift
Transfer of air into the plenum chamber increases pressure and allows the craft to rise.

Air flow
Air is sent down into the plenum chamber of the hovercraft from the main fan.

Inside an LCAC hovercraft

What are the components of a hovercraft that enable it to float?



Rudders

Flaps at the back control the hovercraft like an aircraft, directing airflow in certain directions to allow it to be steered.

Thrust fans

The hovercraft gains its propulsion from these backwards-facing fans, normally mounted on the back of the vehicle. Some use ducted fans, others favour naked propellers.

Lift fan

Air is pumped into the plenum chamber by the main fan in the centre of a hovercraft. Although some hovercraft divert air from the thrust fans instead, lift fan designs are much easier to construct.

Hull

The hull is where you'll find the driver, passengers and cargo of the hovercraft. It sits on top of the cushion of air that keeps the vehicle aloft.

Air

Hovercraft float on top of a large cushion of air that greatly reduces drag and friction, allowing the vehicle to travel over almost any terrain.

Hovergap

When the amount of air escaping through the gap between the skirt and the ground is being equally replaced by air from the lift fan, the hovercraft is at its maximum height.

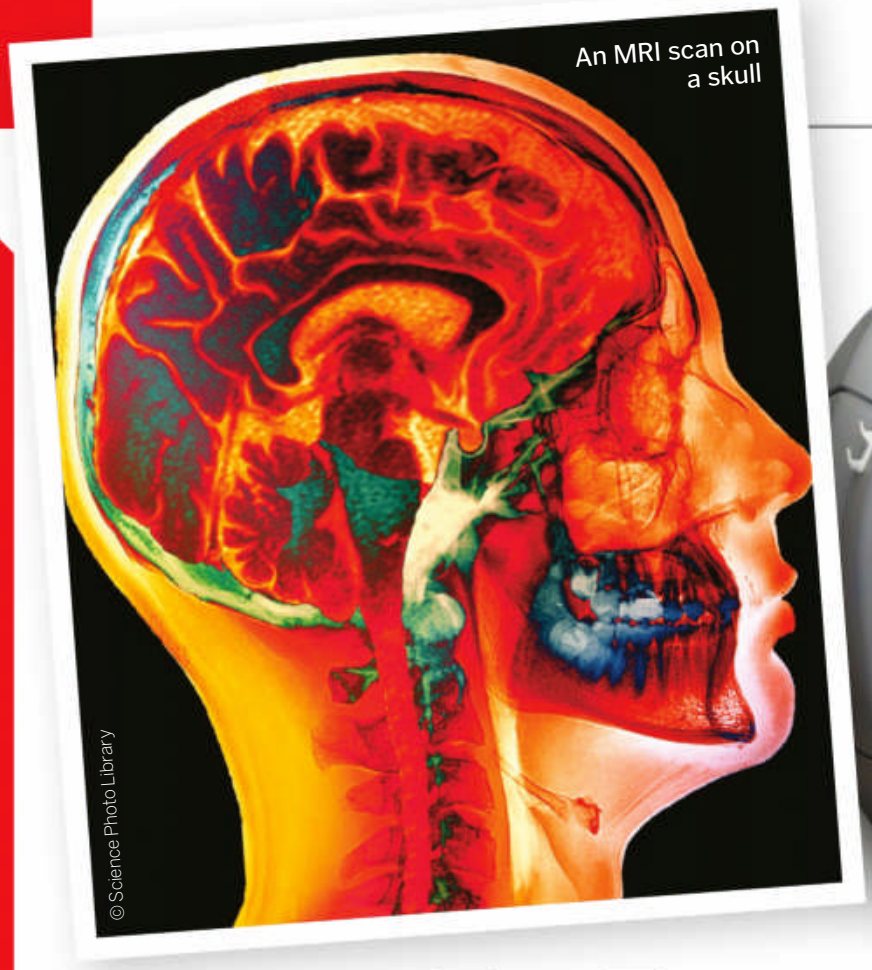
Lift

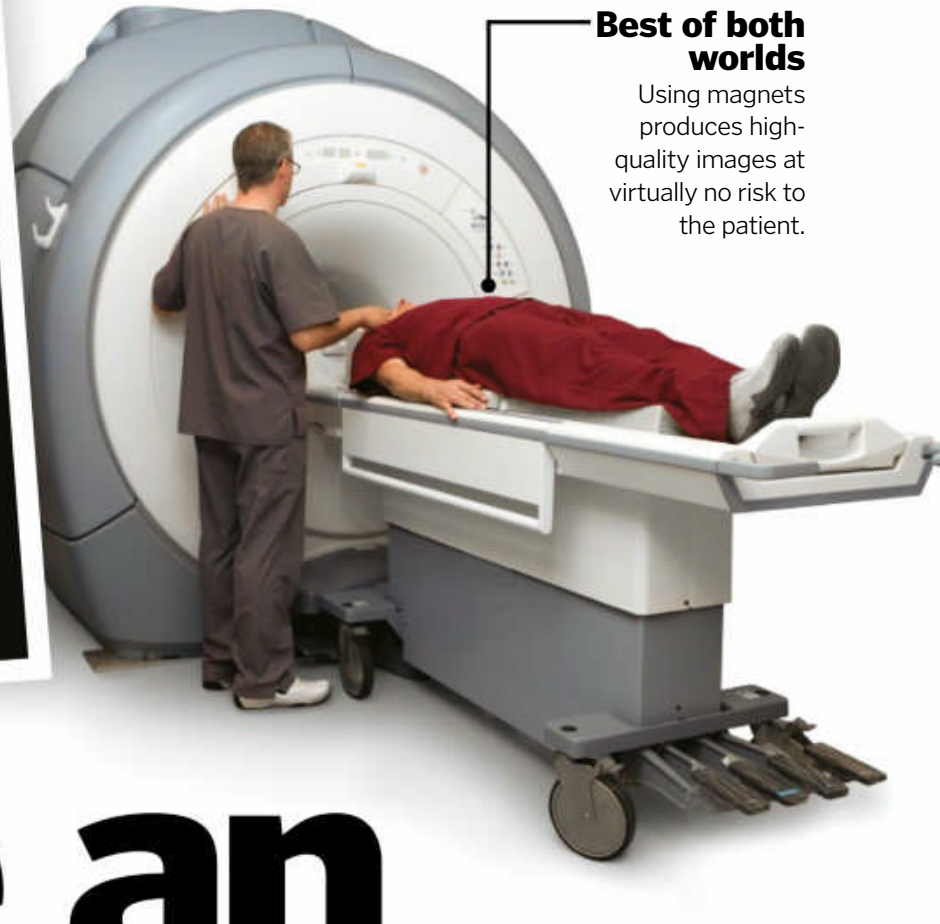
When the pressure of air underneath the hovercraft is greater than the weight of the hovercraft, the vehicle will rise up to a height of a few metres.

Smaller hovercraft use mostly the same techniques as their larger counterparts

© Ankara

Worldwide military forces have many different uses for hovercraft





Inside an MRI scanner

When doctors need the highest quality images possible they turn to MRI scanners, but how do they work?

Doctors often plan treatments based on imaging. X-rays, ultrasound and CT scans provide useful pictures, but when the highest quality images are needed, doctors turn to MRI scanners. While CT scanners use X-rays and therefore expose the patient to radiation, magnetic resonance imaging (MRI) uses powerful magnets and is virtually risk free.

MRI scans are obtained for many medical conditions, although since they are expensive and complicated to interpret, they certainly aren't as easy as taking a chest x-ray. They are used when planning surgery for rectal cancers, assessing bones for infection – called osteomyelitis – looking at the bile ducts in detail for trapped gallstones, assessing ligamental damage in knee joints and assessing the spinal cord for infections, tumours or trapped nerves.

Physicists and engineers use and manipulate the basic laws of physics to develop these incredible scanners for doctors to use. MRI scans provide such details because they work at a sub-molecular level; they work on the protons within hydrogen atoms. By changing the position of these protons using magnetic fields, extremely detailed pictures can be obtained of tissue, organs and bone. Since these pictures rely on the tiny movements of these tiny particles, you need to lie very still during the scan.

Planning from the detail

The detail provided by MRI scanners enables doctors of all specialties to plan a patient's treatment. When footballers damage their knees, an MRI scan will tell if the ligaments are ruptured. Knee surgeons can then reconstruct the damage, often arthroscopically via keyhole incisions. MRI scans are used to characterise a variety of tumours, such as those of the rectum – the lowest part of the colon – and within the brain. MRI scans give enough detail to determine the size and stage of the tumour. This helps specialist surgeons plan whether the tumour is resectable, and also how to perform the operation.

MRI's key lies in its ability to differentiate soft tissues – it can even tell the difference between infected and normal tissues. Infections within bones are best identified using MRI, and then surgeons can plan whether to treat with antibiotics, an operation or – if the infection has spread too far – an amputation.

Slice-by-slice images

Specially wound coils, known as gradient coils, allow for the detailed depth imaging which creates slice-by-slice pictures. While the main superconducting magnet creates a very stable magnetic field, these gradient coils create variable magnetic fields during the scan. These fields mean that the magnetic strength within the patient can be altered in specific areas. Since the protons realign at different rates in different tissue types, the relationship between the strength of the field and the frequency of the emitted photons is different for various tissues. Detecting these differences allows for very detailed images.

Powerful computers outside the main machine then reconstitute all of this data to produce slice-by-slice images. Depending on what's being scanned, 3D reconstructions can then be created, such as for identifying brain tumours.

The MRI scanner

It's a big, high-tech machine. There are different varieties all around the world – found in hospitals, medical research centres and even zoos – but they all work on common principles of manipulating the laws of physics

© Philips Achieva 3.0T TX images courtesy of Philips

Radiofrequency transmission
A radiofrequency transmission causes the protons to flip around, and turning this off causes the protons to realign. This movement releases energy, which is detected by the scanner to create pictures.

Enhancement
Contrast agents are used to enhance the contrast between tissue types. For examining joints such as the shoulder or knee, contrast can be injected directly into the joint prior to the scan. For blood vessels, an intravenous contrast is injected during the scan.

Bang bang!
The gradient coils are switched on and off rapidly, altering the magnetic field in specific tissue areas. As they switch on and off, the coils contract and expand by tiny amounts; this produces a loud noise which is heard as a series of booming bangs.

Looking for tumours
Since the protons in different tissue types return to their normal state at different rates, they give off different frequencies of energy, and so contrast between different types of tissues can be seen. This allows identification of a brain tumour from normal cells.

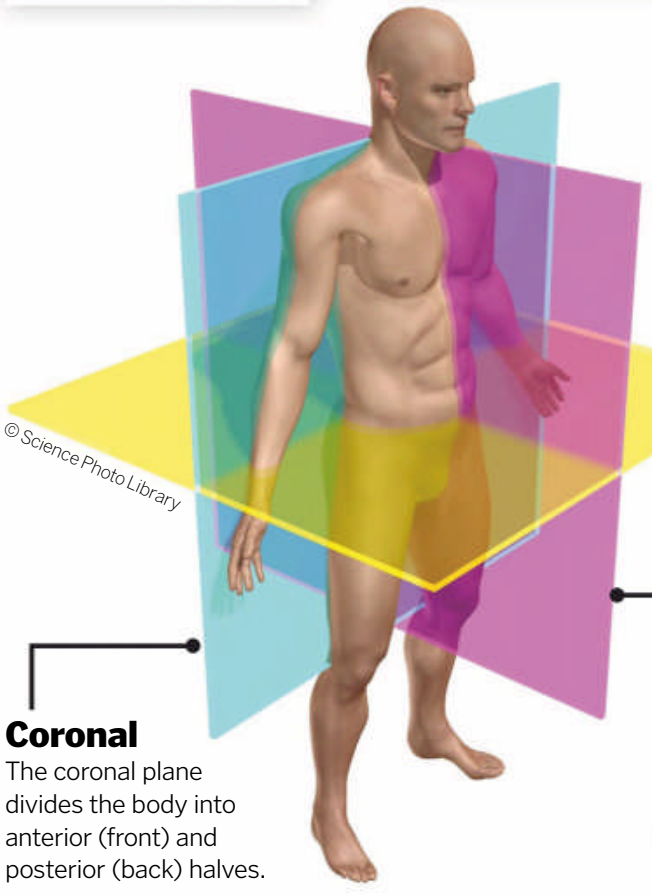
Superconducting magnets
These powerful magnets create very stable magnetic fields, which align protons within the body's hydrogen atoms. The magnets are cooled to near absolute zero, and so are well insulated from the patient.

The tunnel
The tunnel which the patient lies in is very narrow; some patients don't fit. There are small lights and a radio with headphones to keep you comfortable.

The computer
Once the changes in energy have been detected within the scanner they are transmitted to powerful computers outside the scanner. These transform the data into useful images.

Gradient coils
These coils produce much weaker, variable magnetic fields compared to the superconductors. These gradient fields are specifically targeted to certain tissues, allowing for depth and detailed tissue type differentiation.

Lie here
The patient lies down on a narrow plastic 'table' outside the machine, which is then advanced slowly into the tunnel.

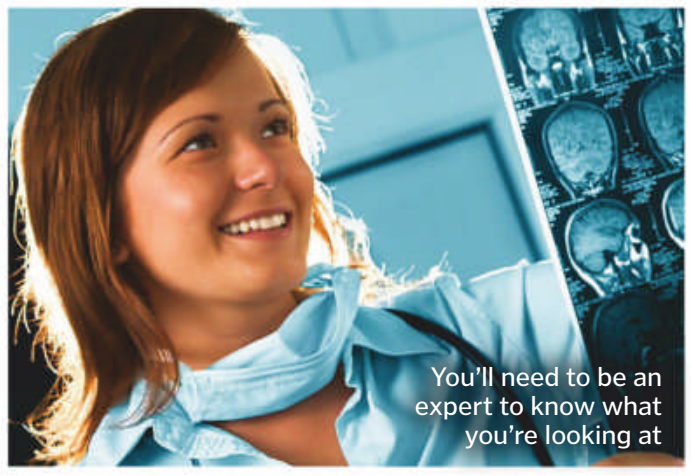


© Science Photo Library

Transverse
The transverse plane is a horizontal plane which divides the body into superior (upper) and inferior (lower) parts.

Coronal
The coronal plane divides the body into anterior (front) and posterior (back) halves.

Sagittal
The sagittal plane moves down the midline of the body and divides it into left and right.



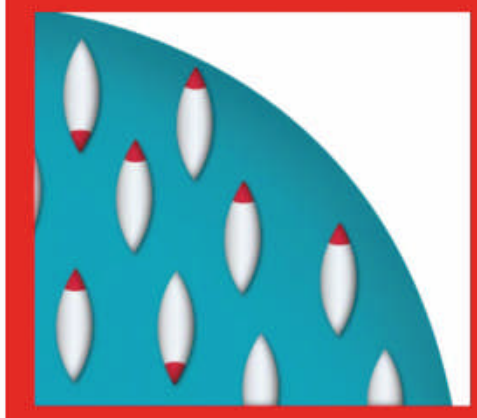
You'll need to be an expert to know what you're looking at

Which direction?

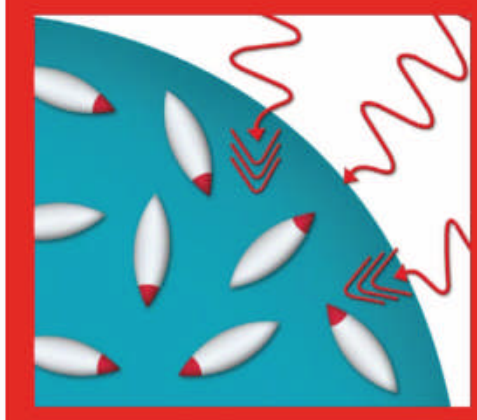
Medical teams need to communicate using the same terms so it is clear what they are looking at. The cross-sectional images produced by MRI scanners are extremely complex, but this is why they are so useful. The terms to the left are the imaginary lines that provide cross-sections. The planes can be moved across the body to look at whole organs or areas.

MRI atoms

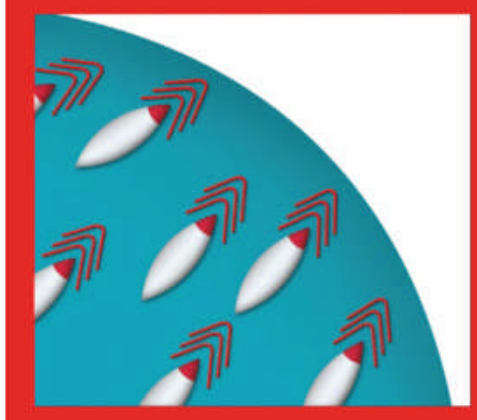
It's a matter of reading the alignment



Lining up
Hydrogen atoms contain just one proton and emit tiny magnetic fields. When placed in a stronger magnetic field – the one produced by the magnets – these protons line up in the direction of the field.



Flip and spin
The scanner emits a radiofrequency through the patient, which flips the spinning direction of these aligned protons. The frequency is at just the right pitch, producing a 'resonance' energy – hence magnetic resonance.



Flip back
Once the radiofrequency is removed, protons degrade back to their original positions. As they do they release tiny amounts of radiowave energy in the form of photons. It is these changes that build the detailed pictures.

Converting to pictures

Different magnetic strengths produce different frequencies in the protons, which are also affected by the different types of body tissues. The resultant energy given off by realigning the protons is interpreted by a computer to produce detailed images.

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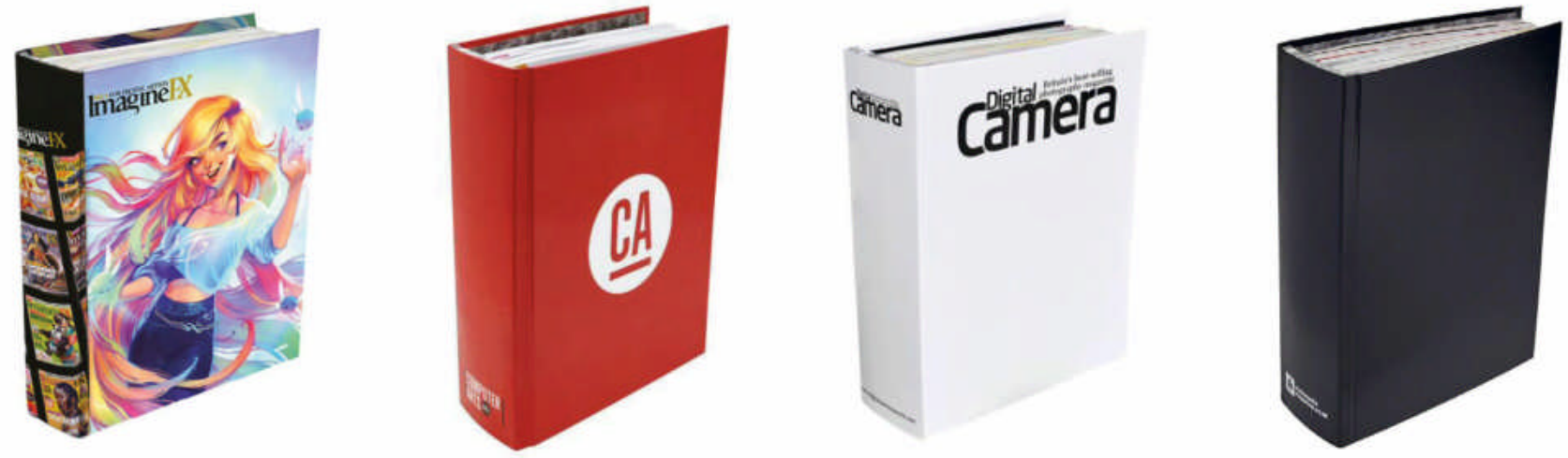

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SPOOKY SPACE PHENOMENA

How It Works ventures beyond Earth to discover the creepiest celestial objects in the cosmos

Words by **Ailsa Harvey** and **Laura Mears**

Orion's witch

This wispy outline, with its hooked nose and curved chin, bears a striking resemblance to the profile of a traditional fairy-tale villain. It is known as the Witch Head Nebula.

The Witch Head Nebula – officially IC 2118 – is a reflection nebula, so it does not produce any light of its own. It is found in the constellation of Orion, west of the blue supergiant star Rigel. Rigel is one of the brightest objects in the night sky, between 40,000 and 100,000 times more luminous than the Sun.

Even though it lies over 40 light years from the nebula, the blue light that Rigel pours out into space illuminates the spooky silhouette of the Witch Head Nebula. It doesn't provide enough energy to ionise the gas and make it glow, but the light scatters as it passes through.

The dust that comprises the nebula scatters blue light more easily than it scatters red, so Rigel's blue shade is intensified. This is the same physical phenomenon that makes Earth's sky appear blue – Rayleigh scattering.

© NASA/STScI Digitized Sky Survey/Noel Carboni

The nebula forms the shape of a witch's side profile, seen looking to the right here

Face on Mars

Can you spot the face just above the image's centre?

© The Viking Project, NASA

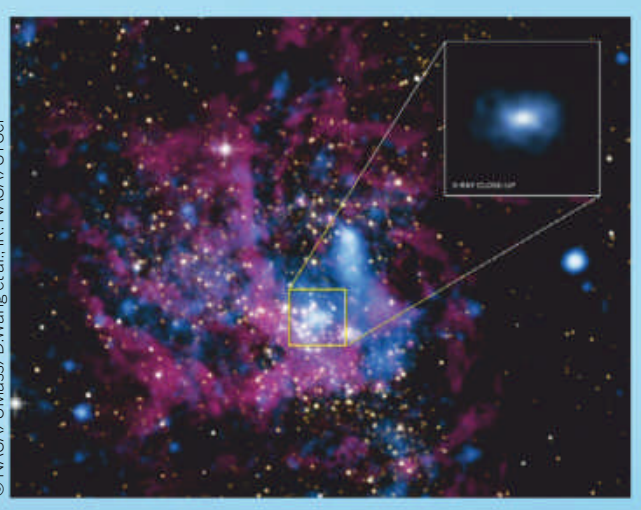
Will we find signs of life on Mars? It's a question many have asked before, but when the Viking 1 mission beamed back this picture of the planet's surface, it showed potential signs of life that were a bit too close to home. Eerily emerging from the rocky surface of the Cydonia region is a human face, wearing a stern expression.

Formed by a combination of the light, shadows and angle that the photograph was taken from, a second flyby confirmed that the majority of these perfectly formed shapes were caused by a trick of the sunlight. However, it didn't stop multiple theories of this figure's past life.

Star swallowers

It's hard to imagine something so powerful that even light can't survive it. Black holes are the all-absorbing beasts found in most galaxies, and at the centre of the Milky Way, a supermassive black hole can be found in the direction of Sagittarius. A supermassive black hole can contain a billion times more mass than a typical black hole, and only a few have been confirmed. The one at the centre of our galaxy has a mass around 4 million times that of our Sun, and is called Sagittarius A*.

While giving the illusion of being empty space, black holes are the opposite. It is their exceptional density of matter that creates a powerful gravitational field. Anything that enters the vast range of its gravitational influence will be pulled towards its core. At a critical threshold within this range that's known as the 'event horizon', it becomes impossible to escape the black hole's gravitational pull. Any object that passes this – from particles of dust to entire stars – will be swallowed up.



© NASA/UMass/D.Wang et al., IR: NASA/STScI

This image of the Milky Way shows the black hole Sagittarius A* at the centre

Black hole anatomy

How do these objects manipulate light?

© NASA/JPL-Caltech

Zombie stars

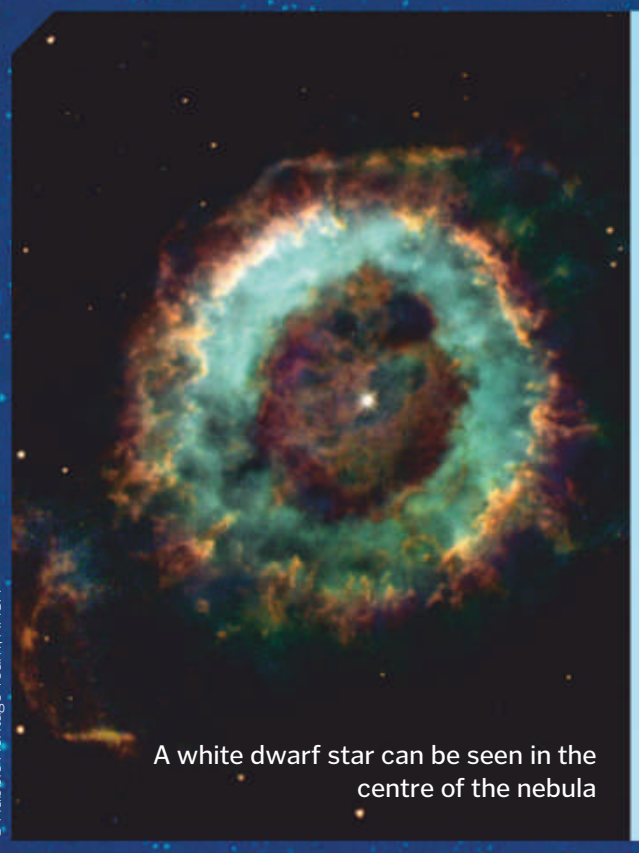
Supernovae are violent explosions in space, and new evidence suggests that some might leave behind zombie stars. Type Ia supernovae happen in binary star systems where a white dwarf star is stealing hydrogen gas from its companion. As more and more matter accumulates, the white dwarf can become unstable, leading to a dramatic explosion that completely destroys the star.

Type II supernovae are more dramatic, and are caused by the death of a massive star. As it runs out of fuel, a star crunches in on itself, releasing vast quantities of energy and leaving behind a dense neutron star – or sometimes a black hole. Until recently it was thought that exploding stars were always destroyed by the blast, but in 2012 scientists revealed a new type of survivable supernovae. Like Type Ia supernovae, Type Iax supernovae are the result of white dwarf stars in binary systems, but this time they are stealing helium gas instead of hydrogen. The result is a much smaller explosion, allowing the damaged star to reappear once the dust has settled, like a zombie raised from the dead.

In 2013 the Hubble Space Telescope captured a picture of one of these weak supernovae, SN 2012Z, in galaxy NGC 1309, which is 110 million light years from Earth. In 2015 Hubble trained its Advanced Camera for Surveys on the supernova remnant to see whether the star survived or not.

These white dwarf stars steal hydrogen from another star until they reach a critical mass

© NASA



A white dwarf star can be seen in the centre of the nebula

© Hubble Heritage Team, NASA

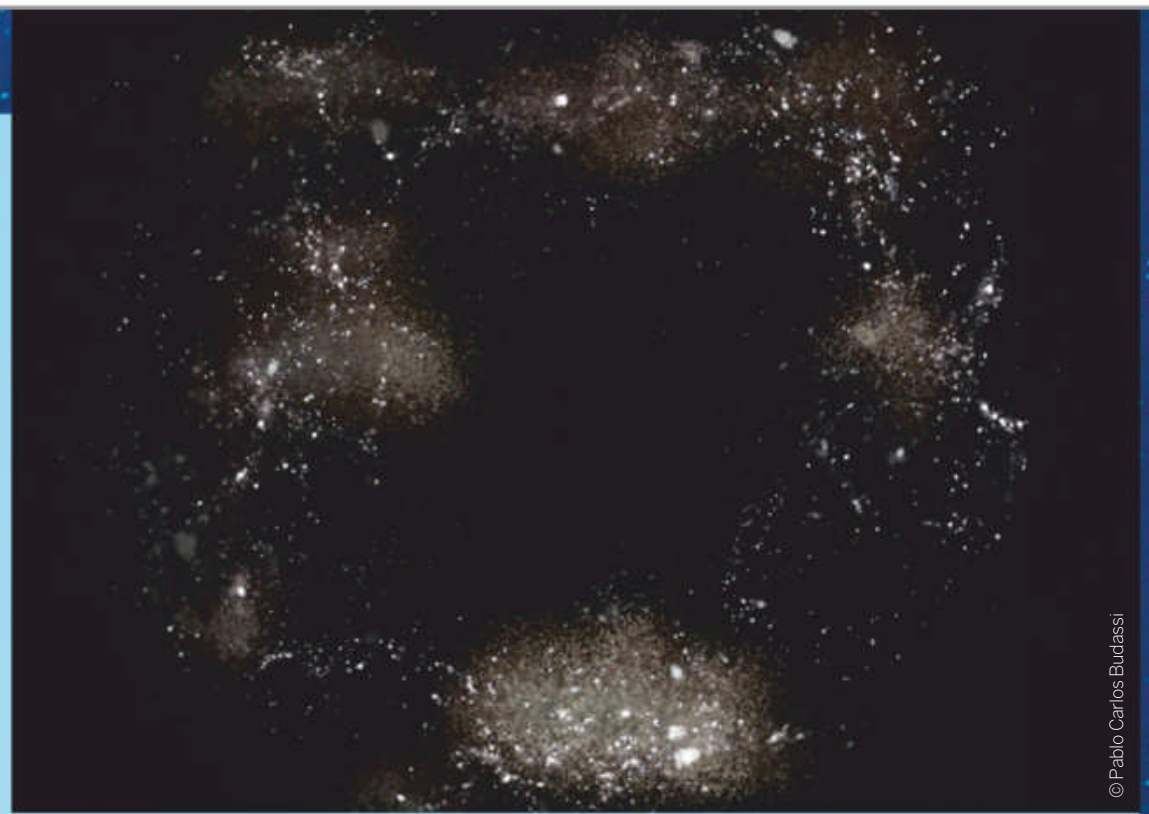
Little Ghost Nebula

The wispy halo of the Little Ghost Nebula surrounds a white dwarf star in the direction of the constellation of Ophiuchus. The white dwarf emits high-energy ultraviolet radiation that slams into the clouds of dust and gas surrounding it, exciting the particles and causing them to glow. The main ring is made from a combination of ionised hydrogen, oxygen and nitrogen, and each emits different wavelengths of radiation.

The Little Ghost Nebula is a planetary nebula, created as the star at its centre ran out of fuel. In fact, it's a ghostly premonition of the fate of our own Solar System.

Once similar in size to our own Sun, the star at the heart of the Little Ghost Nebula eventually ran out of hydrogen fuel, and as it switched to using helium, its temperature soared. The intense heat caused the star to swell, turning it into a red giant.

The red giant tore through its supply of helium quickly, generating carbon in the process. The heavy ash crunched down towards the core of the star, and as it tumbled inwards, some ignited, producing shocks that jettisoned the outer layers of the atmosphere into space. The dust and gas that spilled out formed the Little Ghost Nebula.



This map shows some of the closest voids to Earth

© Pablo Carlos Budassi

The darkest place in space

If you're someone who fears not knowing what lies ahead when darkness falls, you definitely wouldn't want to find yourself in the vicinity of the Boötes void. Also called the 'Great Nothing', this area of space contains the fewest galaxies, and therefore the least light. Discovered 700 million light years away from our planet, the void is home to just 60 galaxies. While this many galaxies combined would create a huge amount of light, in an area with a diameter of 250 million light years, this light is insignificant. An average area of space this size would usually hold around 10,000 galaxies.

Described as a supervoid, many suspect that it formed when multiple voids joined together, growing further in emptiness.

If our galaxy had been one of the 60 in this void, it's estimated that it would have taken us until the 1960s to discover that other galaxies existed, instead of Edwin Hubble's discovery in 1924. It would also make the dead of night an even darker occurrence, with less points of distant light occupying the sky above. Next time the stars are visible, let it serve as a reminder that Earth is not as isolated as it may sometimes seem.

Dying eye

Contained within a bright ball of light, an abstract oval converts this planetary nebula into a cat's piercing eye. The repeating dust shells surrounding it were created by a series of explosions as the star released gas from its outer layers. Nebulae can create a range of abstract shapes, and this one bears similarities to a mysterious feline pupil.

Named the Cat's Eye Nebula (NGC 6543), it has about 11 rings. Each one is a spherical bubble, with a bright outer edge creating the eye's perimeter. When the dying star began exploding, it ejected its contents in 1,500-year intervals. 1,000 years ago it became a nebula when it lost the last of its material.

Today the eye can be seen watching over the Milky Way in the northern constellation of Draco. Holding its shape for centuries, this image of the galaxy is used by scientists as a fossilised record of one of the final stages of this star's life.

The Cat's Eye Nebula was one of the first planetary nebulae discovered

© NASA, MAST, STScI, AURA and Vicent Peris (OAUV/PTeam)

SPACE'S GHOSTLY SOUNDTRACK

SCAN TO HEAR IT!

JUPITER'S ROARING BARRIER

Being the most massive object in the Solar System after the Sun, Jupiter also has a colossal magnetic field. When NASA's Juno spacecraft passed this barrier back in 2016, it recorded a two-hour-long roar as the field deflected the solar wind.

COMET SCATTER

Even the smallest dust particles can be deadly in space. As they hurtle through space, they can impact anything in their path with great force. In 2011 NASA's Stardust spacecraft recorded the sound of being battered by rocks and dust from Comet Tempel 1.

SATURN'S RADIO WHISTLE

Picked up as an isolated whistle, Saturn's natural radio waves add a haunting tune to the wind. These waves are produced by the planet's changing magnetic field.

PLASMA PERCUSSION

We might not be able to pick up the sound of space plasma, but probes have recorded the emulation of stormy plasma seas. These raging, rhythmic waves can be heard across the abundance of extremely hot gas in space.

THE CHORUS OF GANYMEDE

Jupiter's largest moon can make a great noise. When converted into sound, its electromagnetic waves sound like a forest of screeching birds.

Aliens on Venus?

A recent discovery has led scientists to reconsider the likelihood of life on the second planet from the Sun. If it's there, how will we find it?

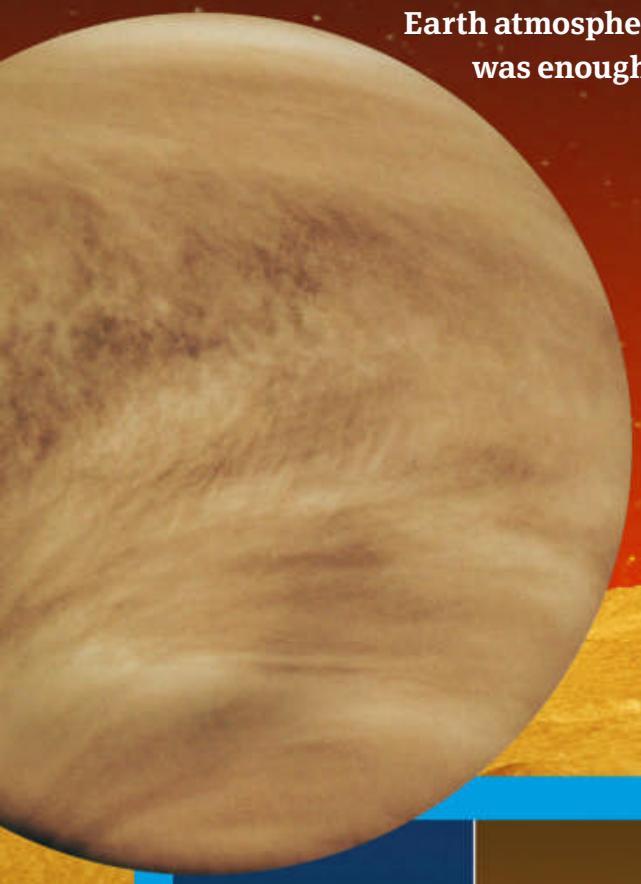
Words by **Ben Biggs**

"Life ekes out an existence in some incredibly hostile places"

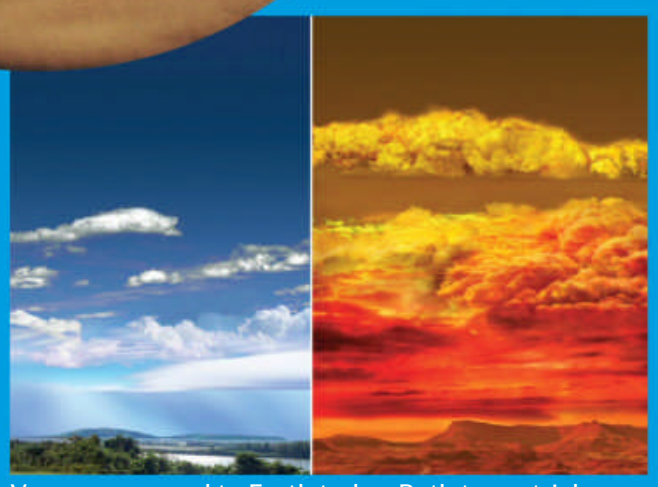
As far as hospitable places for life go, Venus is far from ideal. A dense atmosphere wraps the planet up in a blanket-like layer of gases that traps heat, making it the hottest planet in the Solar System at over 460 degrees Celsius. The pressure on the surface is over 90 Earth atmospheres, which was enough to crush the Soviet spacecraft Venera 5 and 6 flat when they landed in 1969. Its barren landscape is covered in active volcanoes, and the clouds in its atmosphere are composed of up to 96 per cent sulphuric acid, the same kind of caustic stuff you'd find in a car battery.

But for 60 years this hasn't stopped scientists from considering it a likely planet to find life in our Solar System, partly because life ekes out an existence in some incredibly hostile places on Earth: the crushing ocean pressures at the bottom of the Mariana Trench, the boiling and acidic waters of the Grand Prismatic Spring and kilometres high in the Earth's stratosphere. There's also a thin layer in the Venusian atmosphere where conditions are quite comfortable for life, a safe haven within Venus' own Goldilocks zone around the Sun.

In 2017, scientists from Cardiff University decided to have a closer look at the atmosphere of Venus with a powerful telescope that scans in radio wavelengths. They picked up a signature of rare phosphine gas that seems likely to have a biological origin. Two years later the team used the



An ultraviolet image of Venus' clouds, taken by NASA's Pioneer orbiter in 1979. © NASA



Venus compared to Earth today. Both terrestrial planets sit in the Sun's 'Goldilocks zone', and for a billion years or so were very similar

Why we're excited about phosphine

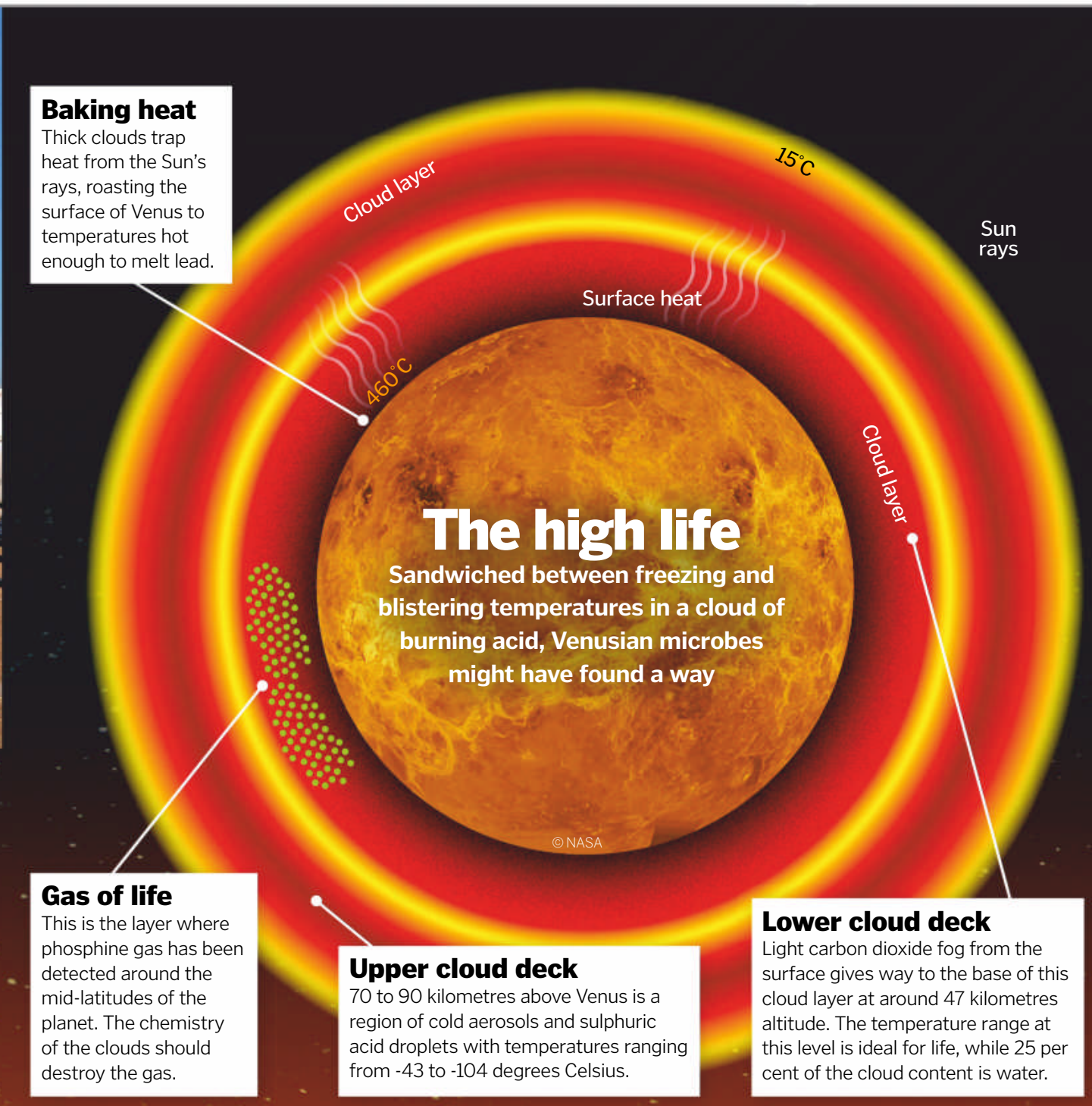
Phosphine is produced by a few living species on Earth, such as the bacteria that respire in the absence of oxygen in marshland and in the guts of some animals. It's poisonous to us and any organism that breathes oxygen, and it's also hard to make in nature. It can be created by the extreme conditions of a gas giant's atmosphere where no life is possible, but it shouldn't be found on a rocky terrestrial planet like Venus – and certainly not in the large quantities it's been detected in.

Ruling out a quirk of Venusian chemistry that we're yet to learn about and possible errors in the Cardiff University team's measurements, it just leaves microbial organisms as the source of the gas. How could life have ended up there? It's thought that at the time life was taking off on Earth around 3 billion years ago, Venus was a habitable planet with liquid water on the surface. Around 2 billion years later a runaway greenhouse effect – possibly triggered by massive volcanic activity – had turned Venus into a hellscape. Any life may have effectively been pushed into a thin layer of the atmosphere, the only place on the planet where it could survive.

19 of the 66 antennae of the European Southern Observatory's ALMA telescope array, recently used to observe phosphine gas in Venus' atmosphere

© ALMA (ESO/NAOJ/NRAO)/W.Garnier

European Southern Observatory's Atacama Large Millimeter/submillimeter Array (ALMA) to pinpoint large quantities of phosphine between 50 and 60 kilometres altitude, where the atmospheric pressure is Earth-like and the temperature can be a balmy 27 degrees Celsius. It's stirred up the scientific community, and only with further investigation will we know for sure whether this gas was created by living organisms.



Baking heat
Thick clouds trap heat from the Sun's rays, roasting the surface of Venus to temperatures hot enough to melt lead.

Gas of life
This is the layer where phosphine gas has been detected around the mid-latitudes of the planet. The chemistry of the clouds should destroy the gas.

Upper cloud deck
70 to 90 kilometres above Venus is a region of cold aerosols and sulphuric acid droplets with temperatures ranging from -43 to -104 degrees Celsius.

Lower cloud deck
Light carbon dioxide fog from the surface gives way to the base of this cloud layer at around 47 kilometres altitude. The temperature range at this level is ideal for life, while 25 per cent of the cloud content is water.

The high life
Sandwiched between freezing and blistering temperatures in a cloud of burning acid, Venusian microbes might have found a way

Almost all of Venus' surface features are named after famous women

75%
At least three quarters of Venusian clouds are acid

360kph
The wind in Venus' top cloud layer travels faster than the world's fastest recorded hurricane

20 parts per 1,000,000,000
The phosphine is calculated to be at least 1,000 times more abundant than on Earth

1989
It's been over 30 years since NASA last sent a probe to Venus

If you could walk on Venus' surface, it would feel like walking a mile underwater on Earth

© Emerezhko

A scale replica of the Soviet Venera 7 lander, built to survive extreme pressures, which landed on Venus on 15 December 1970

What's next?
The team still needs to confirm the presence of phosphine by further verifying the observations they pulled from the data, but they're not stopping the search for signs of life in Venus' atmosphere. If they can confirm that phosphine is present in large quantities, it would help inform the objectives of several Venus missions that are in the pipeline. It would mean that missions like DAVINCI+, a finalist for NASA's Discovery program, could look directly for life as it plunges through Venus' atmosphere. The presence of phosphine gas on Venus also puts an interesting spin on the observation of exoplanets orbiting stars light years away from Earth. In the near future we might be able to search for the presence of life on planets far beyond our Solar System.

© NASA / Getty

BRAIN DUMP

Because enquiring minds need to know...

DID YOU KNOW?

At around four months old, babies will begin to roll over in their sleep

An artist's impression of a black hole sucking in a star

Could the black hole at the centre of our galaxy get so big it could swallow the Milky Way?

Aiofe Finnegan

The supermassive black hole at the centre of our Milky Way galaxy is called Sagittarius A* and weighs approximately 4 million solar masses, or 4 million times the weight of our Sun. This massive monster gobbles up everything that comes close – including light – and grows in size the more material it takes in. The heavier this gargantuan gobbler becomes, the stronger its gravitational influence, allowing it to suck in even more sustenance. However, even with a massive gravitational reach, there's not much chance a black hole could eat an entire galaxy. It's also theorised that there's a limit to how big they can grow – about 50 billion solar masses. **NR**

© NASA

WANT ANSWERS? Send your questions to...

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Do birds swap the wing they put their head under during sleep?

Stephen Conn

Birds often look like they have their heads under a wing when they are just resting their heads on their backs, becoming submerged slightly within their feathers. This can be observed when watching ducks sleeping by a pond. Turning their heads to their backs rests their neck muscles, and they may well readjust this position to stay comfortable throughout the night. **AH**

© Getty

DID YOU KNOW?

The average person sweats around one litre an hour when exercising

Why are vegetables usually green?

Ruslan

Vegetables don't need to produce colourful fruits to attract animal pollinators for seed dispersal, instead reproducing through pollen produced by flowers or asexually, essentially cloning themselves. Like all leafy green plants, many vegetables are green thanks to the pigment chlorophyll, which turns sunlight into food for the plant through photosynthesis. **SD**

© Getty

Source: Wiki/John Wootton

Who was the last king or queen of Britain to fight on the battlefield?

Mahendra Kumar

George II was the last British monarch to actually lead his troops into battle, on 27 June 1743 in the War of the Austrian Succession. He rode his horse and led the charge against the French in the Battle of Dettingen in southeast Germany. Modern monarchs like Prince Harry, William and Charles have each had a stint of military service, and Prince Harry secretly saw frontline combat in Afghanistan as a forward air controller in the army. However, after the press discovered this, his deployment was cut short as the Ministry of Defence felt that the knowledge of his presence would increase Taliban attacks and put everyone in greater danger. **BB**

© Getty

Varifocal lenses make switching between near and far sight easy

How do varifocal glasses work?

Michael Laws

Varifocal lenses allow wearers to view things in clear focus at various distances. This means that one pair of glasses allows you to see while reading, driving or simply looking at the world around you. By changing power across the lens, moving your eyes to a specific section will allow you to see something close up or far away just as clearly. These points on the lens can be positioned depending on the user's natural vision, so lenses can be tailor-made for an individual. **NR**

BRAIN DUMP

Why can't I run as fast when it's a humid day?

Grant Sheldon

Increased humidity means that there is more moisture in the air, and less space for sweat to evaporate into. Sweating becomes less effective in cooling you down because the air is less capable of holding the extra moisture that evaporates from your sweat. You can't run as fast because your body is trying to prevent you from overheating.

This excess moisture increases the temperature of your body, which in turn impacts the pace you can run at. Your body is putting more energy into adjusting its temperature, so it can't use as much to power your muscles. **AH**

Moisture-wicking clothing can help to draw moisture away from your body

© Getty

DID YOU KNOW?

There are 1,097 vegetable species cultivated worldwide

What is the most extreme place life could exist in the universe?

Ewelina Nowak

We already know some carbon-based life forms can exist in unlikely places on Earth, like at the bottom of the ocean or in boiling pools of water. Extremophiles like tardigrades are microscopic creatures that can survive in the vacuum of space, being blasted with radiation and without food or water for years. Recently it's been suggested that 'rogue' planets, which exist too far from their parent star to benefit from their heat and light, could be a good place to find life outside our Solar System: some of them may provide the necessary energy to kick-start life via their hot cores and radioactive elements. And because they are far from a star system, they may not have had the intense period of extinction-level meteorite impacts that Earth has experienced. **BB**

©NASA

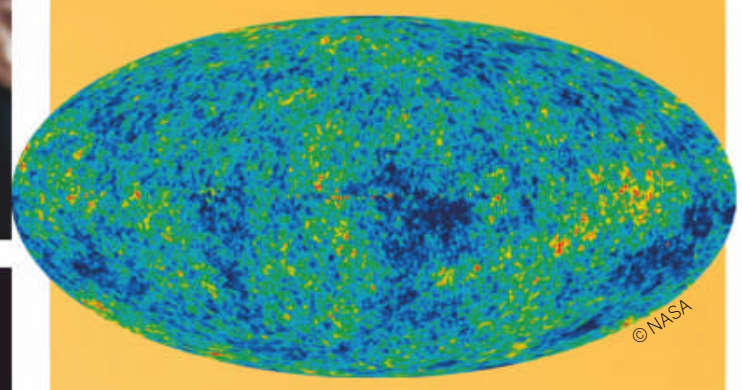
Rogue planets have been ejected from their solar systems by huge gravitational events, and could be a good place to find extreme life

© Pixabay/ Yvonne Huijbens

How do people etch inside a block of glass?

Jeff Jacobs

A high-temperature laser is programmed by a subsurface laser engraving machine to cut material at a specific point. This location needs to be set to a point inside the block by programming the depth as another dimension. The see-through quality of glass makes this possible, as the laser's light can travel through the material. The material used is usually a specially selected crystal glass to prevent refraction throwing the laser off its exact target. **AH**



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Do we know exactly where the big bang happened in the observable universe?

#AskHIW

The Big Bang didn't happen in a single location within our universe: it happened everywhere, all at the same time. We know this because of the way that galaxies cluster in similar patterns throughout the universe. Also, the afterglow of the Big Bang, known as the cosmic microwave background (CMB), is isotropic, meaning it's almost exactly the same everywhere in all directions, with only one part in a thousand being different. **BB**

© Getty

Can we beam electricity?

Nishat Singh

Yes, we can, in a way. This is seen in wireless charging, where power can be transferred over short distances using magnetic fields. The possibility of beaming power over longer distances using beams of microwave radiation or lasers is being looked into, with one application being satellites that can harvest solar power and beam it to Earth for use. **NR**

© Getty

Why do trees like silver birch have papery bark that peels off so easily?

Saim Higgs

Much like our skin cells or the sleeve of scales that snakes shed, bark serves as a protective coating against invading pathogens. Beneath the surface, plant cells are continually growing and producing more tree bark. As these cells die, they become the flaky, thin strips of birch bark and fall away, taking any parasites, pathogens or damage caused by environmental factors – such as frost – with them. **SD**

Silver birch trees can shed A4-sized strips of bark at a time

If we could teleport, would we still need cars, trains or other vehicles?

Ellie-Louise Sykes

In short, the answer is we don't know. Although the crew aboard the Starship Enterprise seem to have nailed the science, in real life we are nowhere close to understanding the practical demands of teleportation. What we do know is that in order to simultaneously move an object from one place to another, it first must be destroyed and reconstituted back into its original form. For humans that's pretty much a death sentence. However, teleportation has been achieved on a quantum level by 'teleporting' two particles through a computer chip using a principle of physics called quantum entanglement. **SD**

We're a long way off human teleportation, but it could be possible

DID YOU KNOW?

A star with a mass 20 times that of our Sun's can produce a black hole when it dies

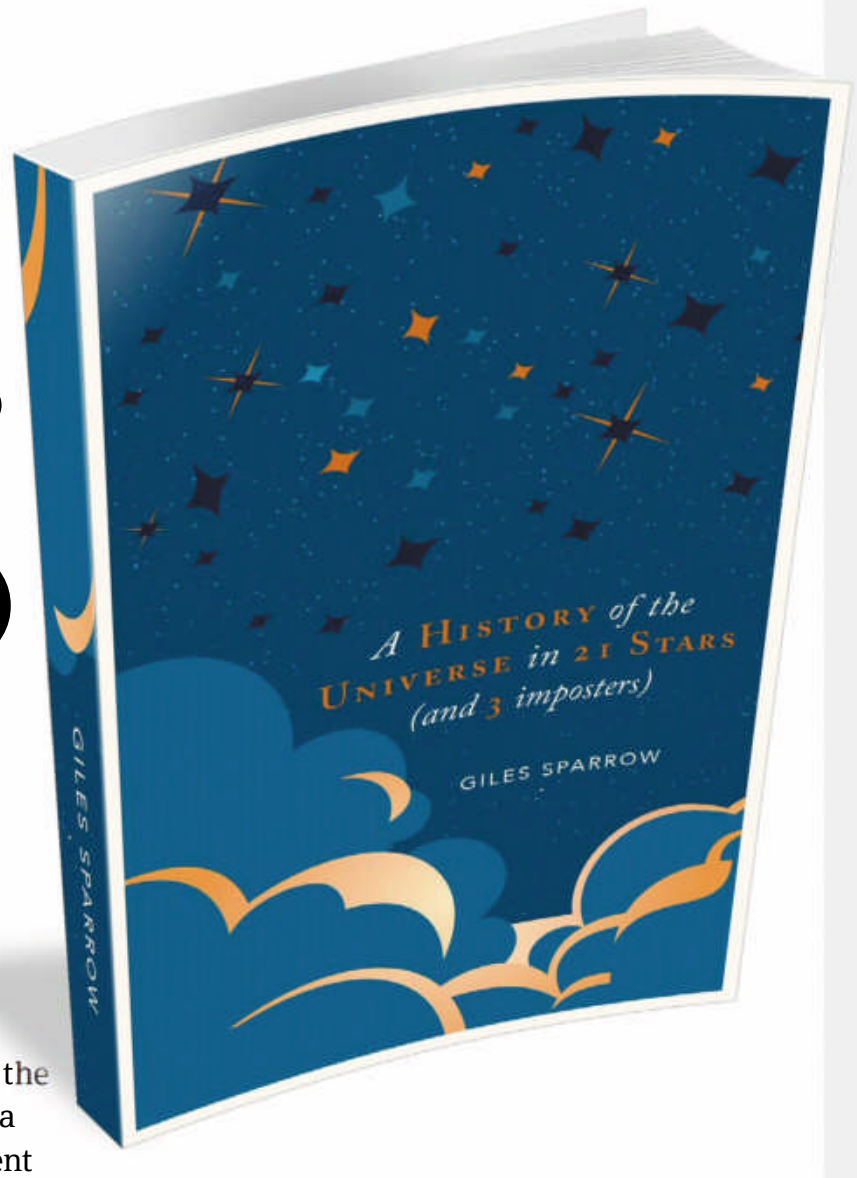
© Shutterstock

BOOK REVIEWS

The latest releases for curious minds

A History of the Universe in 21 Stars (and 3 imposters)

Shining a light on the cosmos



- Author: **Giles Sparrow**
- Publisher: **Welbeck**
- Price: **£12.99 / $14.95**
- Release: **Out now**

Did you know that when you look up at the sky on a clear night, you can only see a few thousand stars? Even with a decent telescope you'll only be able to see a couple of million, every single one of which is within our own galaxy. As a **How It Works** reader there's a pretty good chance you did know this, but that's what astronomer and author Giles Sparrow had to work with when he set out to write *A History of the Universe in 21 Stars (and 3 imposters)*. Even standing on the shoulders of a thousand years of astronomy giants such as Galileo and Hawking, it still sounds presumptuous to claim to be able to chart the history of the universe using just a handful of stars within our cosmic locale. But as Sparrow explains in his prologue, with modern science and technology at his fingertips and a considerable amount of perseverance, this is well within the realms of possibility.

So how did he choose just 21 – plus those three imposters – from the billions of stars in our galaxy to put on his literary catwalk? Fortunately we can describe the life cycle of entire groups of stars just by looking at one example: Sparrow highlights the bright orange giant Aldebaran as a K-type star whose colour tells us a lot about its age, temperature and a myriad of other stellar characteristics. He talks about the history of Aldebaran's observation from Earth that, given it's one of the brightest and most distinctive stars in our sky, goes back thousands of years. In a blow-by-blow fashion he charts the scientific and astronomical developments that eventually led to the spectral sequence by which most stars can be classified today: O-B-A-F-G-K-M.

> "A simple and very effective format for describing our universe"

It's a simple and very effective format for describing our universe. Eta Carinae is an example of the truly gargantuan size some stars will become, Cygnus X-1 is an 'imposter' and an example of the black hole afterlife that awaits some stars. Our own Sun, with its well-defined history, is an example of an average-sized, common G-type star.

It's very well-written and fairly accessible to anyone who has a good general awareness of space topics. It'll certainly give amateur astronomers and space fans a broader perspective of the cosmos.

★★★★☆

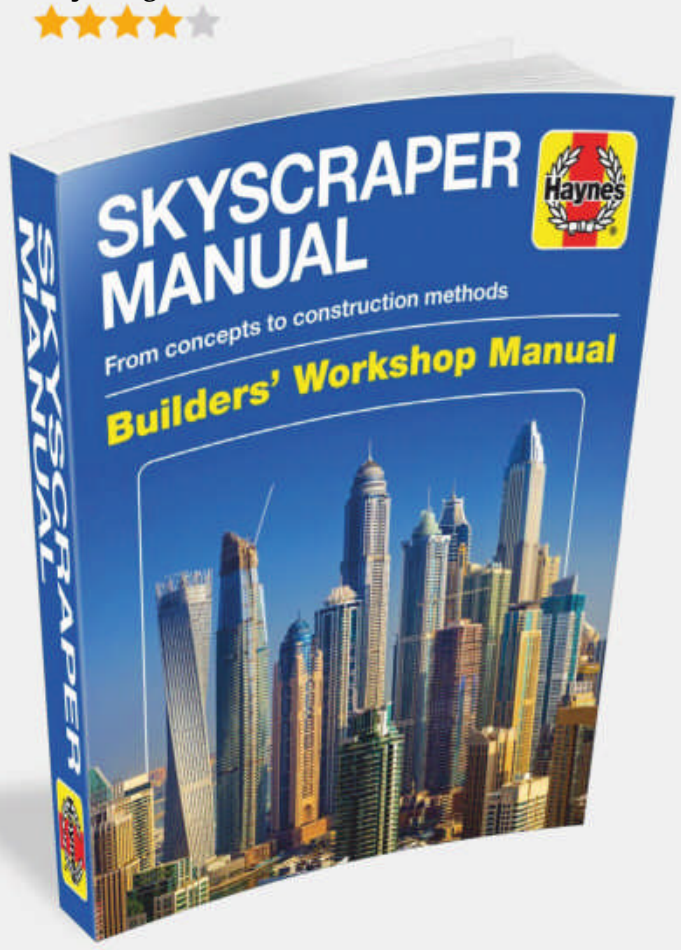
Skyscraper Manual

Builders' Workshop Manual

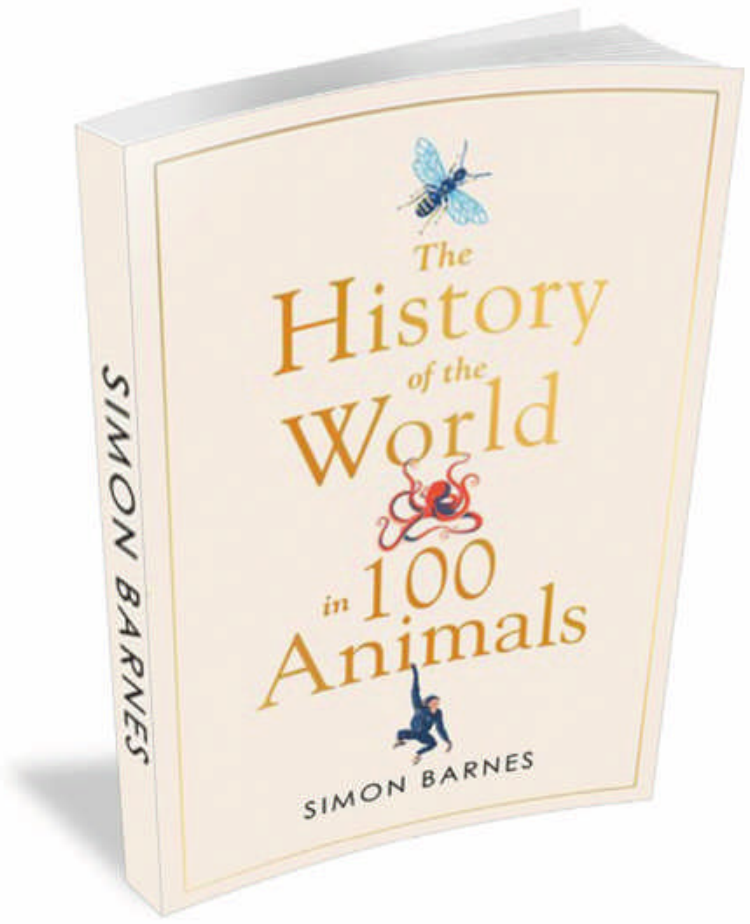
- Author: **Dave Parker and Alexandra Wynne**
- Publisher: **Haynes**
- Price: **£25 / $36.95**
- Release: **Out now**

From Stone Age creations to modern-day Goliaths around the world, this manual not only explores the history of the skyscraper's evolution but also gets into the nitty-gritty of how they are built, with the assistance of informative illustrations. Insightful and surprising in parts, this guide details the blood, sweat and tears it takes to construct a skyscraper and explores the failures that come with building these behemoths. This includes the 'Walkie Talkie' building in London, whose concave façade reflected so much sunlight onto the street it melted the parked cars below. Whether you're looking to build the foundations of your knowledge or you're an architect in your own right, this Haynes guide is a must-read.

★★★★☆



> "Insightful and surprising in parts"



The History of the World in 100 Animals

Discover some of the most impactful species on Earth

- Author: **Simon Barnes**
- Publisher: **Simon & Schuster**
- Price: **£25 (approx. $32.50)**
- Release: **Out now**

From the flea that almost wiped us out to the cattle that helped build civilisations, Barnes outlines the animals that have had the largest impact on our lives – and how we have affected theirs – in this thought-provoking book. Filled with insightful science about the lives of these carefully selected animals, Barnes seamlessly blends the roles each has played in shaping modern-day humankind. It quickly becomes clear, as you venture through each chapter, how intertwined we are with our animal neighbours. However, Barnes doesn't sugarcoat things when it comes to talking about the shortcomings of the human impact on some animal species. The 100th animal, the polar bear, seems only fitting as the last animal on the list. As the poster species for climate change, Barnes calls us to action to preserve not only our own species, but also all of those that made us who we are today.

★★★★★

Jessie the Jellyfish

How can we save our friends in the ocean?

- Author: **Laurie Newman**
- Illustrator: **Sophie Cregan**
- Publisher: **Blue Jay Books**
- Price: **£6.99 (approx. $9.10)**
- Release: **Out now**

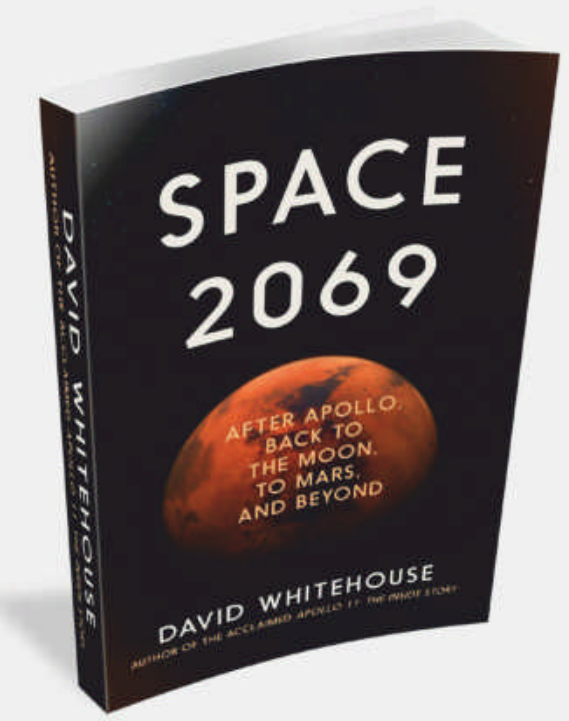
Jessie's friends have vanished from the ocean, causing her to mistakenly befriend a plastic bag. How did this happen, and how can Jessie get them to return? If there's one thing young children can relate to, it's the joy of having friends. This is the underlying focus of this book, used to carry the important issue of pollution to younger readers.

Providing an engaging story, packed with smooth rhymes and beautifully absorbing illustrations, this book displays our impact on the undersea world in a child-friendly way. After the few remaining creatures resort to making friends and homes out of our rubbish, the uplifting ending shows the sea as it should be.

> "Carries the important issue of pollution"

Throughout the book, the intriguing story and fun poetic narrative expertly highlight an important message in a way that children aged around three to seven can understand. Next time children think about dropping rubbish, they might just remember Jessie and her friends.

★★★★★



Space 2069

Back to the Moon, to Mars and beyond

- Author: **David Whitehouse**
- Publisher: **Icon Books Ltd**
- Price: **£16.99 / $27**
- Release: **Out now**

In 1969, humans first walked on the Moon. Now, halfway towards Apollo 11's 100-year anniversary, this is the best time to track how much space exploration has evolved, and to analyse the progress that is likely to be made by 2069. Whitehouse has done just that, combining the history of space travel with his expert knowledge to predict the next 50 years. Accounts from the future could be mistaken for fiction, but each insight is based on current scientific findings, the space industry's progression and confirmed future missions. What makes this book so gripping is the vision of what could truly be made possible.

Whitehouse takes you on a three-part journey. The first outlines the importance of the 2024 mission that will take us back to the Moon. The second tackles the hardships that may be faced in safely placing people on Mars and utilising space tourism. The third explores beyond what is planned. How far will space travel take us? Where are our limits? The final chapters set your imagination rocketing. *Space 2069* is a book that looks to the future just enough to fascinate, but not too much as to be unrealistic. It is ideal for all space enthusiasts who want to learn more about significant past missions, the true possibilities and the hurdles that will stand before our future goals.

★★★★★

BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

QUICKFIRE QUESTIONS

Q1 Which of these is not a common food allergy?
- Peanuts
- Celery
- Mustard
- Red meat

Q2 What does the 'M' in MRI stand for?
- Molecular
- Massive
- Magnetic
- Mega

Q3 Which of these plants is not toxic?
- Water hemlock
- Potato fruit
- Okra
- Castor beans

Q4 In what year was the first monster truck 'Bigfoot' invented?
- 1883
- 1979
- 1944
- 1910

Q5 When was the last witch trial held in England?
- 1684
- 1717
- 1812
- 1944

Q6 What is a quasar?
- A high-energy laser beam weapon
- A galactic nucleus
- A supermassive black hole surrounded by a gassy accretion disc
- An interstellar cloud

Spot the difference

See if you can find all six changes between the images below

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

5	7			8		9		
4	8	9	7		1	5	3	
	2		5	4				1
1	5	6		3	4	2	7	
	9	2		1	5	6	4	3
8	3	4	6	7	2			9
3	1		2	6		4	9	
2		5	1	9	8			
9				5		8		

DIFFICULT

	3	8		6				5
		2	7					
	9						1	
					3		9	
6				8	4	7		
5							8	4
					1			7
			4		9	8		1
2	1							6

© Getty

What is it?

Hint: The seed of this tree can be used to play a traditional game...

A .....

L	A	C	A	H	O	O	V	E	R	I	C	M	E	P
N	E	R	T	C	R	I	C	H	T	E	R	O	B	E
D	I	O	V	E	N	E	L	O	E	N	A	M	C	T
E	X	E	C	V	M	A	G	R	H	O	J	A	K	I
Y	Q	B	E	T	W	B	A	Q	U	E	R	G	V	W
F	O	N	U	E	I	M	E	A	S	T	E	N	A	P
E	U	M	O	A	T	N	E	C	I	R	T	E	M	O
S	R	W	I	H	C	E	H	D	M	U	S	T	P	U
E	O	H	G	B	H	R	J	Y	N	O	Z	I	I	L
A	B	I	F	H	M	O	N	A	O	S	H	C	R	K
B	N	A	C	K	Y	J	E	X	U	G	O	V	E	R
E	Q	C	A	N	I	P	F	E	D	O	B	T	I	B
I	S	E	V	P	X	O	T	N	I	J	E	L	R	F
R	O	M	W	N	I	X	O	T	W	E	I	C	A	H
M	O	N	S	T	E	R	M	E	L	P	A	O	J	B

Wordsearch

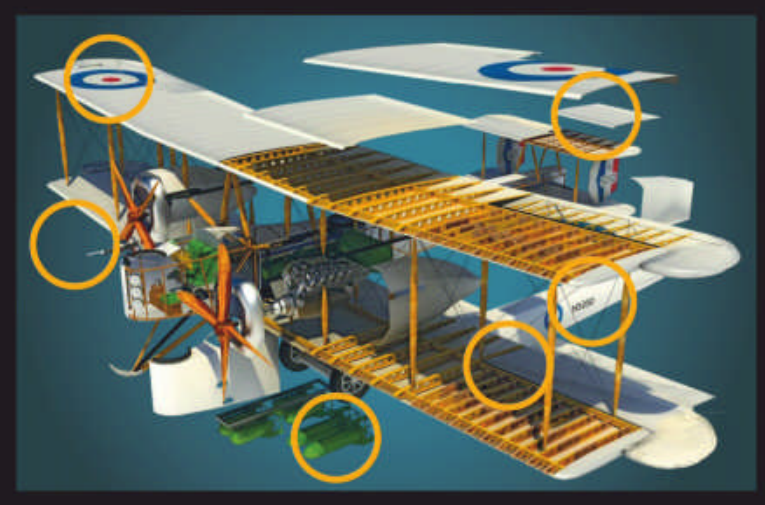
FIND THE FOLLOWING WORDS...

NIGHTMARE
TOXIN
VAMPIRE
VOID
WITCH
PEANUT
HOOVER
LAB
MONSTER
MAGNETIC
VENUS
RICHTER

Check your answers

Find the solutions to last issue's puzzle pages

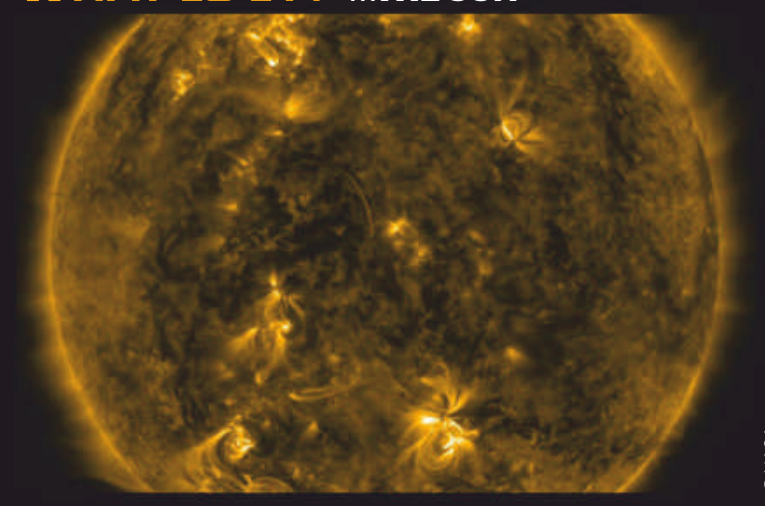
SPOT THE DIFFERENCE



QUICKFIRE QUESTIONS

Q1 Argentinosaurus
Q2 42,195 metres
Q3 Nearly light speed
Q4 Six litres
Q5 Lithium
Q6 75 years

WHAT IS IT? ...THE SUN



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WIN!
ONE OF THREE SMART TRACKERS

This month we are giving three lucky winners the chance to win a Chipolo bundle, which includes the Chipolo ONE and Chipolo CARD smart t ackers, allowing you to keep an eye on belongings such as your keys, phone and wallet with ease.

WORTH £49!

For your chance to win, answer the following question:

What is a fear of spiders called?

a) **Claustrophobia** b) **Trypophobia** c) **Arachnophobia**

Enter online at **howitworksdaily.com** and one lucky winner will win!

Terms and Conditions: Competition closes at 00:00 GMT on 19 November 2020. By taking part in this competition you agree to be bound by these terms and conditions and the Competition Rules: **futuretcs.com**. Entries must be received by 00:00 GMT on 19/11/2020. Open to all UK residents aged 18 years or over. The winner will be drawn at random from all valid entries received, and shall be notified by email or telephone. The prize is non-transferable and non-refundable. There is no cash alternative.

HOW TO...

Practical projects to try at home

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

Get in touch
Send your ideas to...
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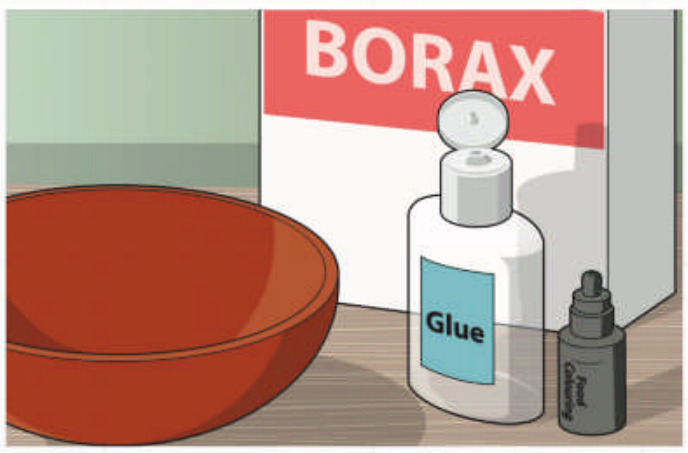
How to make slime

Watch as this satisfyingly gooey substance forms in your hands



1 Gather your ingredients

You will need borax, PVA glue, food colouring, warm water and two bowls. In countries where you can't buy borax, you can use contact lens solution and baking soda instead.

2 Create the borax solution

Place one teaspoon of the solution into one of the bowls and add one cup – or measure out 240 millilitres – of warm water. Stir this solution until it is clear.

3 Measure the glue

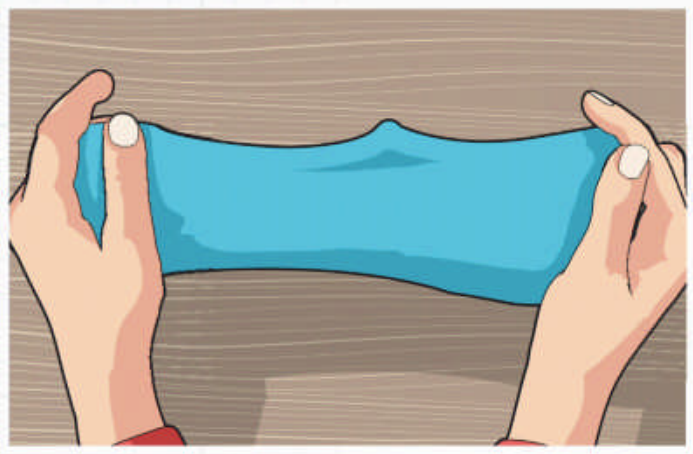
Weigh out 110 grams of PVA glue and pour this into your second, still empty bowl. White glue will make the slime stretchier than if you use clear glue.

4 Create your colour

While this step isn't vital, a couple of drops of your chosen food colouring will provide a personalised touch to your slime's appearance. Don't add too much or it could stain your hands.

5 Thicken the slime

Take your bowl of the solution and add it to the glue one spoonful at a time. You should see your mixture sticking together and becoming slime-like. If you add too much water, pour it off.



6 Reduce stickiness

The slime should have begun to clump together. Once this has happened, knead the mixture with your hands to make it less sticky. Add more solution if it remains too wet.

7 Stretch and play

When you're happy with the feel of your slime, it is ready to play with. Pull, squeeze and make new shapes with the slime in your hands. When finished, store it in an airtight container.

SUMMARY

The two main components dictate the consistency of your slime. Slime can flow like a liquid, but not in the same way as water. Its viscosity doesn't remain constant, displaying solid and liquid properties. It can flow through your fingers, but toughen as you squeeze it. The glue traps water and produces liquid properties, while the borax stiffens it. The end product forms due to the protein molecules in the glue binding with borate ions in the borax powder or contact lens solution.

Had a go? Let us know!
If you've tried out any of our experiments – or conducted some of your own – then let us know! Share your photos or videos with us on social media.

NEXT ISSUE
Make a toilet roll Solar System

© Illustrations by Ed Crooks

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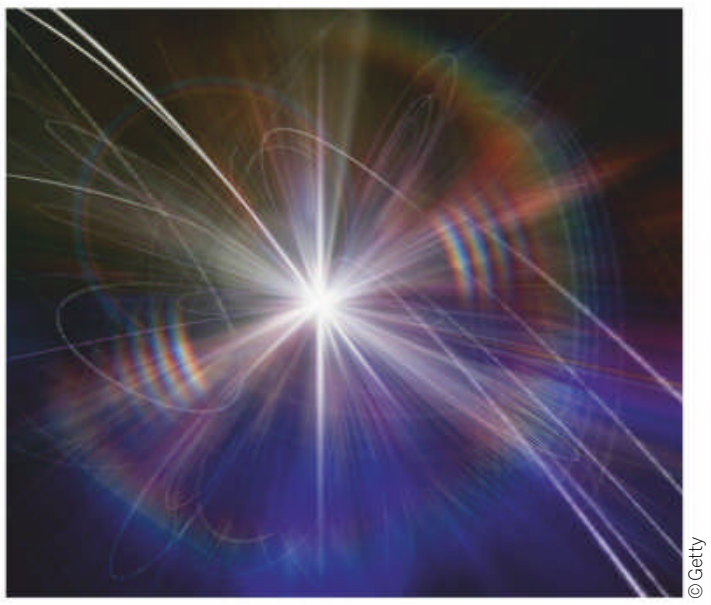
INBOX
Speak your mind...



© Getty

The Higgs boson is also referred to as the 'God particle'

Science discovery

Dear **HIW,**

What is the biggest scientific discovery of this millennium?

Jason Oxley

There have been many great discoveries in recent years, especially with technology advancing so quickly, but perhaps one of the most important and highest profile science breakthroughs of this millennium is the discovery of Higgs boson in 2012. The existence of this particle explains why all other particles have mass and fills in some major gaps in scientific theory.

This is just one of many big finds that have occurred this millennium, with each contributing to different areas of science. In the last decade alone, signs of ancient life have been discovered by the Curiosity rover on Mars, new life-saving vaccines have been developed, such as the Ebola vaccine in 2019, and on average biologists have named 18,000 new species each year.

Get in touch

If you have any questions or comments for us, send them to:

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howitworks@futurenet.com howitworksmag

WIN! JESSIE THE JELLYFISH

© Blue Jay Books

This is the story of a lonely jellyfish. With no friends to be found on the reef, Jessie makes friends with a floating plastic bag. But can the sea be cleaned up in time so Jessie's friends can return to party and play?

Letter of the month

Tracking fire

Dear **HIW,**

I would be super interested in learning more about fire mapping. I live in Australia and was affected by the intense fire season at the start of the year. I would love to learn more about how these massive bushfires are predicted and mapped when they are in progress, and how firefighters know where the fire is going to go and how to best fight it. It seems like a fascinating science, and pretty important given the worsening fire seasons due to climate change.

Kate Wattchow

Thank you for your letter, Kate. We hope you and those around you managed to stay safe during this year's fire season. Australia witnessed soaring temperatures and rapid fire spreading during these recent fires.

The fire mapping you mention played a vital role in monitoring and predicting the route of devastation. One way these fires were mapped was through satellite data. Operated by NASA, their hotspot detection program is able to identify fires and track them in real time.

NASA's Terra and Aqua satellites circle the planet daily and are equipped with sensors that can detect heat radiating from specific areas. In some cases visual data can confirm that the heat is from flames by capturing high-resolution imagery. Fire alerts are sent to individual organisations such as NASA, who can analyse whether the data displayed is from a bushfire.

When processed, the data is shared online with decision makers, and presents the public with the information they need to keep safe. Firefighters can keep an eye on large areas of land using these images, as well as relying on witness reports.

About 126,000 square kilometres of land was destroyed during Australia's latest bushfire season

© Getty

Four-leaf clovers became a lucky symbol because they're a rare find

© Bellezza87/Pixabay

Lucky genetics

Dear **HIW,**

I was taking a walk in the park one day and saw a clover patch. I saw a four-leaf clover and made it into a sample. My question is: what are four leaf clovers, and what makes them grow an extra leaf?

Kind regards,
Jacob

Thanks for sharing this with us, Jacob. Your find will have made any readers who believe in luck quite jealous. A clover, with three or four leaves, is actually a single leaf of a larger plant. Usually there are three leaflets, but the fourth – and sometimes even more – can appear on the rare occasion it mutates. The reason that this mutation takes place can vary, but it causes an alteration in the DNA, resulting in more than three leaves.

Chernobyl victims

Dear **HIW,**

There were heroes dealing with the Chernobyl disaster, but how many people actually died or suffered serious illness as a result of it?

Stephen Conn

Thousands were evacuated from Chernobyl following the explosion

Following the explosion of a nuclear power plant in Ukraine in 1986, there were many casualties. The answer to your question is not a straightforward one, because many more were affected than those who died during the initial weeks after the incident.

The radiation level was so damaging that those at the scene who survived the blast later suffered deaths from radiation sickness. During the first three months there were 30 deaths of power plant operators and firefighters. The number of people who died in the following years due to health complications from the disaster can only be an estimate. This number is between 4,000 and 27,000.

0 Kelvin, 0 gravity?

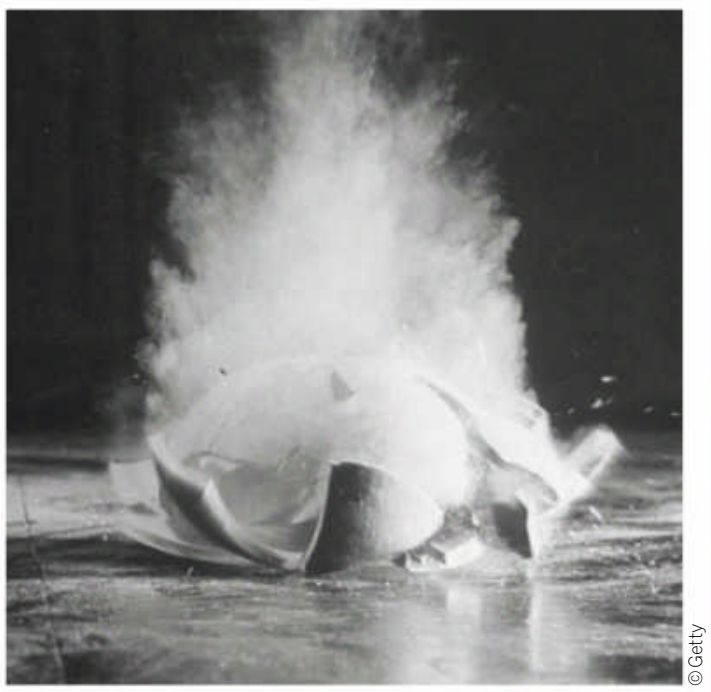
Dear **HIW,**

Here's my next question: is gravity affected at zero Kelvin?

Many thanks,

Arthur Alaphilippe, 11 years old

Another great question, Arthur. Zero Kelvin, or -273.15 degrees Celsius, otherwise known as absolute zero, is the lowest temperature that is theoretically possible. At this temperature particles are said to have little motion because there is no heat energy left to allow them to vibrate. Gravity is separate and independent from temperature, however, and so this force is not thought to be affected by absolute zero.



This rubber ball, at a temperature near absolute zero, shattered as gravity brought it to the floor

What's happening on... social media?

This month on Instagram we asked you: 'What do you think is the scariest discovery ever made?'

@louistyndall
There have been 5 mass extinctions. We may be living in the 6th, called the Holocene extinction

@_rchiesw_in
That if we continue to burn fossil fuels at the rate we are the world will basically die

@louistyndall
The huge collection of plastic floating in the Pacific that has formed a 'trash island'

@definitely.notmax
Covid-19 because it has been the cause of so many losses and casualties

@maia_h3
CRISPR gene editing done unethically on those twins was pretty creepy!

@scimaxfacts
The nuke. It could be so devastating just by the press of a button!

NEXT ISSUE...

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clare.dove@futurenet.com
Senior Advertising Manager **Amanda Burns**
amanda.burns@futurenet.com
0330 390 6036
Account Manager **Garry Brookes**
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FAST FACTS

Amazing trivia to blow your mind

1976

THE WORLD'S FIRST MRI SCAN WAS OF A TUMOUR IN THE THORAX OF A MOUSE

20,000

THE UK'S CORONAVIRUS MEGALAB CAN PROCESS THOUSANDS OF TESTS A DAY

99.1MPH

RAMINATOR CLOCKED IN THE FASTEST SPEED BY A MONSTER TRUCK IN 2014

60,000

FROM 1400 TO 1782, GERMAN-SPEAKING COUNTRIES TRIED AND EXECUTED THOUSANDS FOR WITCHCRAFT

11 BILLION

THERE ARE AN INCREDIBLE NUMBER OF EARTH-LIKE PLANETS IN OUR GALAXY ALONE

THE 'MARE' IN 'NIGHTMARE' IS OLD ENGLISH FOR A DEMON THAT TORMENTS PEOPLE WITH SCARY DREAMS

PHYSICISTS RECENTLY PROVED THAT TIME TRAVEL IS 'MATHEMATICALLY POSSIBLE'

ONE NANOGRAM PER KILOGRAM

BOTULINUM IS THE MOST TOXIC SUBSTANCE KNOWN TO HUMANS: JUST A TINY AMOUNT OF IT CAN KILL

14 YEARS

THE FOUR FACES OF PRESIDENTS ON MOUNT RUSHMORE WERE CARVED OUT OF THE CLIFF FROM 1927 TO 1941

555 TONNES

RUSSIA'S ZUBR-CLASS MILITARY HOVERCRAFT WEIGHS AROUND THE SAME AS 100 AFRICAN ELEPHANTS

THE DNA OF TINY WORMS HAS BEEN FOUND 3.6 KILOMETRES UNDERGROUND IN SOUTH AFRICA

TRUSTED BY PARENTS
LOVED BY KIDS
SUITABLE FOR AGES 7+

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J6037
FORD F-150 RAPTOR

Ford F-150 Raptor
Build an Iconic Model

Ford Raptor is a nameplate used by Ford Motor Company on "high-performance" pickup trucks. In use since the 2010 model year, the Raptor is the highest-performance version of the Ford F-150 and Ford Ranger. Drawing its name from both birds of prey and the velociraptor, the model line is intended as a street-legal counterpart of an off-road racing vehicle. The F-150 Raptor is currently in its second generation; the Ranger Raptor was introduced in 2019 (in markets outside of North America).

Optimized for off-road use, the Raptor is fitted with four-wheel drive as standard equipment, a mid-travel suspension system, and all-terrain tires. The truck is also equipped with the most powerful engine available in the F-150/Ranger lines. Along with wider fenders, the Raptor is fitted with its own grille, replacing the Ford Blue Oval emblem with large "FORD" lettering in the grille.

This vehicle has already become a true icon. You can create your own version at home with this Airfix QuickBuild kit. Recreate brilliant scale models of a wide variety of iconic aircraft, tanks and cars with QuickBuild kits. No paint or glue is required, the push together brick system results in a realistic, scale model that is compatible with other plastic brick brands.

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